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# Sky at Night

#155 APRIL 2018

# ICE MOONS

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Examining 'Oumuamua, our Solar System's mysterious visitor

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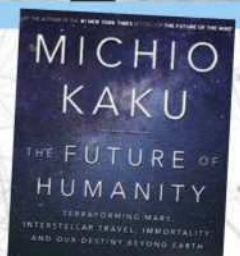


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## This month's contributors include...

**Terena Bell**
**Science writer**

Terena talks to priests at the Vatican Observatory who believe their scientific pursuits reinforce their religious beliefs. *Page 74*

**Paul Money**
**Reviews editor**

Paul enlists the help of a stepladder in order to review a monster of a Dobsonian – but does bigger mean better? *Page 90*

**Elizabeth Pearson**
**News editor**

Elizabeth investigates some of the coolest features of the Solar System, literally. Discover the secrets of ice volcanoes. *Page 36*

**Chris Welch**
**Space engineering expert**

Amidst all the media fanfare, Chris is left wondering whether Falcon Heavy *really* has a commercial future. *Page 38*

# Welcome

## Preparing to explore our Solar System's ice moons

Ask a planetary biologist to list where in the Solar System is most likely to harbour life and occupying several of the top spots will be the icy moons. These frozen satellites of the gas and ice giants may appear to be the last place for life to gain a foothold, but all is not as it seems. On page 36, Elizabeth Pearson peers beneath their surfaces to uncover oceans of liquid water and speaks to the scientists planning missions to these strange cryovolcanic worlds.

It's only with space missions that we have gained such an understanding of the conditions on bodies hundreds of millions of kilometres from Earth. To understand the quality of observations astronomers achieved in the past, astro-adventurers Scott Lange and Nick Foster set off to the 19th-century Lick Observatory in California. See what views of Europa and its parent planet Jupiter greeted them on page 67.

For your own astro-adventure this spring, look no further than page 30. Astronomer Will Gater has six of the best projects for all experiences, taking in views at the eyepiece, objects to sketch and targets to image. There's sure to be something for everyone.

It's a concerning fact that for more and more of us, objects like those in Will's feature are harder to see because of light pollution. As Earth Hour on 24 March asks us to switch our lights off for an hour to highlight the problem, on page 42 lighting engineer Allan Howard is our expert guide to lighting units that will preserve your dark skies.

Enjoy the issue.

**Chris Bramley** Editor

**PS** Our next issue goes on sale 19 April.

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C = on the cover

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Get started with The Guide on page 78 and our online glossary at www.skyatnightmagazine.com/dictionary

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## Regulars

# APRIL'S BONUS CONTENT

**HOW TO FIND IT**

Visit **www.skyatnightmagazine.com/bonuscontent**, select April's bonus content from the list and enter the authorisation code **VEFY6VK** when prompted


# April highlights

## Watch *The Sky at Night*

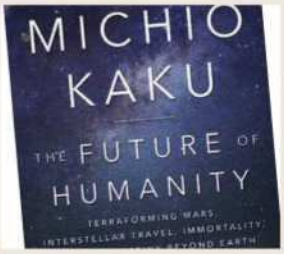
In October 2017, astronomers spotted the first known interstellar object passing through our Solar System: asteroid 'Oumuamua. Chris visits Belfast, where scientists are discovering more about this mysterious object, while Maggie looks at the clues gleaned by astronomers as 'Oumuamua made its way through the Solar System.

### Interview: The Lick Observatory today

Astronomer Dr Elinor Gates reveals how this historic US observatory is searching for new worlds and alien life.

### Astrophoto gallery: readers' nebulae

From the Tarantula to the Witch's Broom: our pick of the best nebulaic astro images sent in by you.




### Audiobook preview: Future of Humanity

Download an audio and PDF excerpt from the latest book by renowned astronomer Michio Kaku.

## And much more...

- ▷ **Hotshots gallery**
- ▷ **Eye on the sky**
- ▷ **Extra EQMOD files**
- ▷ **Binocular tour**
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- ▷ **Observing forms**
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**EVERY MONTH**

### Virtual Planetarium

**With Paul Abel and Pete Lawrence**

Explore April's night-sky highlights with Paul and Pete.

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# Out of the darkness

## Dark nebulae are black pockets of cold dust that blot out starlight, yet may also have been the starting point for the dynamic world we see around us

**VLT SURVEY TELESCOPE, MPG/ESO 2.2-METRE TELESCOPE, 31 JANUARY 2018**

Many celestial objects that capture our imagination are wondrously bright and colourful. But not always. Dark nebulae are dense clouds of dust that blot out the light from distant stars. Historically, they were mistaken as a mere absence of stars but today we know this is not the case. Most nebulae glow in multicolour because they are clouds of dust and gas illuminated by the intense radiation of hot stars, but dark nebulae are so cold and dense they scatter and absorb light as it passes through them; hence their other name – 'absorption nebulae'.

The inky cloud scarring this image is one such dark nebula, known as Lupus 3. Situated just 600 lightyears from Earth, it's part of a larger complex called the Lupus Clouds.

While dark nebulae may look lifeless, the opposite is true. Many are active star-forming regions, containing vast quantities of densely-packed dust; the perfect condition for creating protostars. Using infrared and radio telescopes, astronomers can observe the new-born stars within the clouds.

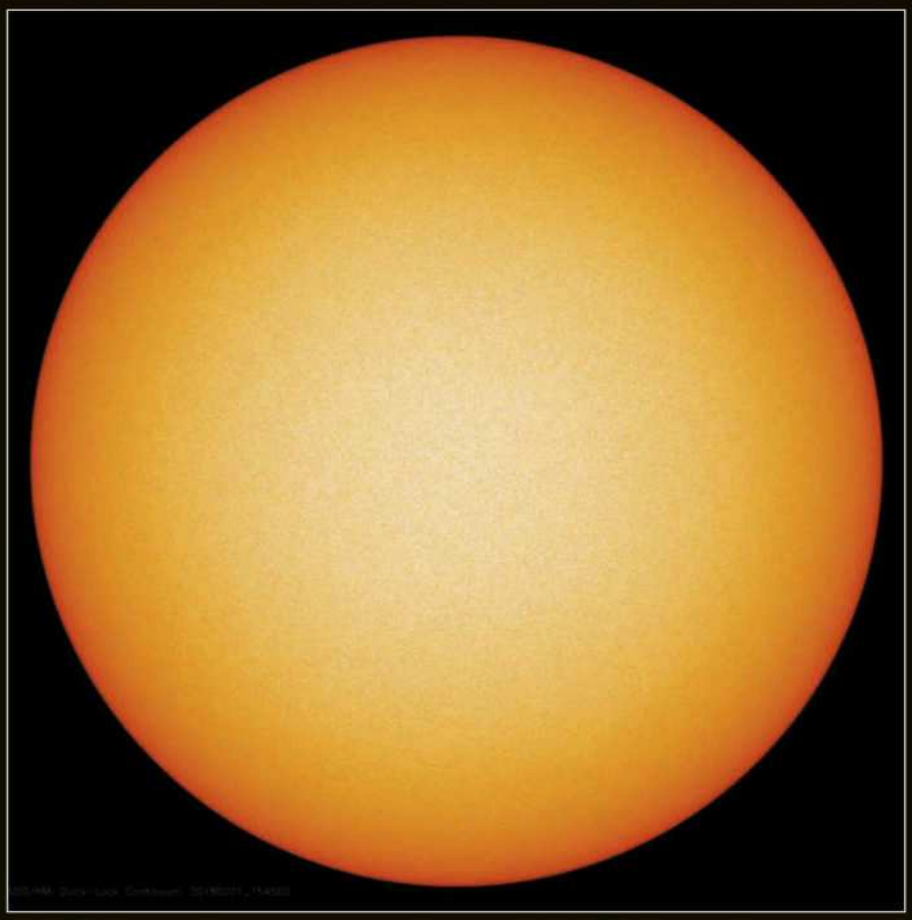
No infrared is needed to see the two bright stars prominent in this image, though. Once obscured by Lupus 3, they have grown hotter, giving off intense radiation and charged particles that have brushed the dark dust aside. It is thought that our own Sun may have gone through a similar process. So, far from being dark, dormant regions, these black clouds may be the basis for life as we know it.

ESO/R. COLOMBARI

## ▲ Spotting an exploded star

**HUBBLE SPACE TELESCOPE, 29 JANUARY 2018**

Astronomers captured this image of spiral galaxy NGC 7331 as they were observing a supernova located close to its galactic core. This exploding star, named SN2014C, caught their attention because in just one year it changed from containing very little hydrogen to containing a lot. Studying a development like this can help piece together clues about a little-understood aspect of cosmology: what happens during the dying days of a star?



## A spotless Sun ▶

**NASA SOLAR DYNAMICS OBSERVATORY, 1 FEBRUARY 2018**

The amount of magnetic activity occurring on the Sun's surface passes through an 11-year phase known as a 'solar cycle'. The current cycle began in December 2008, and next year will approach the period known as the 'solar minimum'. This image is evidence of the approach of this minimum, as it shows an unusually spotless solar disc.

**YOUR BONUS CONTENT**

A gallery of these and more stunning space images

## ◀ Party of five

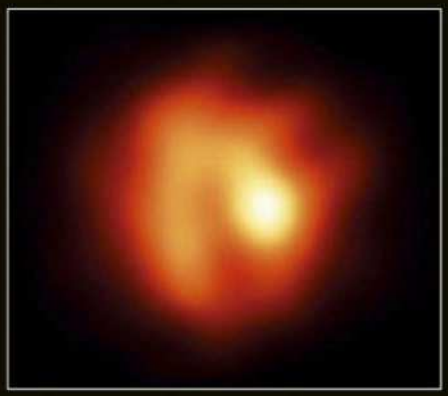
CANADA-FRANCE-HAWAII TELESCOPE, 5 FEBRUARY 2018

This deep, multi-band image was taken as part of a study into the workings of Stephan's Quintet, a group of five spiral and elliptical galaxies (seen as a yellow blob below and to the right of centre). One of the galaxies, NGC 7317, was discovered to have very old, red stars, implying that the quintet is older than expected, and that theories of its formation and evolution may have to be revised.

## ▼ Shedding stellar skin

VERY LARGE TELESCOPE INTERFEROMETER, 9 FEBRUARY 2018

R Sculptor is an asymptotic giant branch star, the name given to low-mass stars late in their lives. These bright red dying stars shed their dusty mass into space, forming bright round objects known as planetary nebulae. The astronomers who created this image infer that the brightest spot is a region with little or no dust at all, exposing the stellar surface.



## Telltale tadpole ▶

MARS RECONNAISSANCE ORBITER, 5 FEBRUARY 2018

This object resembling a tadpole is an impact crater, its tail a valley carved by water draining outwards. Scientists know this because studies of the Red Planet have created a thorough picture of the Martian terrain. They were able to determine that the valley extends across a downward-sloping surface, meaning it must have been carved by water draining outwards, rather than inwards.

ESA/HUBBLE & NASA/D. MILISAVLJEVIC (PURDUE UNIVERSITY), SOLAR DYNAMICS OBSERVATORY/NASA, CFHT/COELUM, JEAN-CHARLES CUILLANDRE (CFHT/CEA SACLAY/OBS. DE PARIS) & GIOVANNI ANSELMI (COELUM), ESO/M. WITTKOWSKI (ESO), NASA/JPL-CALTECH/UNIV. OF ARIZONA

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# Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

**PLUS CUTTING EDGE**



**Our experts examine the hottest new astronomy research papers**

## SpaceX launches FALCON HEAVY ROCKET

### The launch system carried a highly unusual payload into orbit

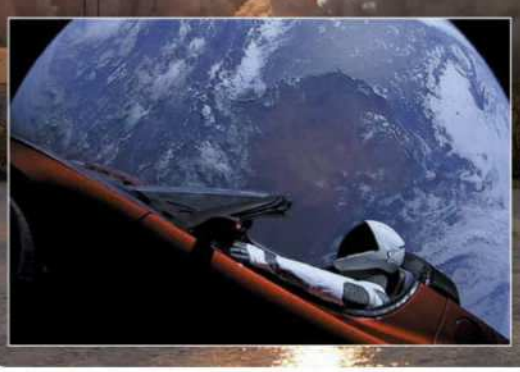
**Spaceflight company SpaceX successfully launched its new Falcon Heavy rocket for the first time on 6 February 2018, and put its payload– a Tesla Roadster 'driven' by a mannequin named Starman – into orbit around the Sun.**

**The rocket has the potential to revolutionise spaceflight. Not only is it the second most powerful space launch system ever built – only the Saturn V was greater – but its three booster rockets are designed to land after use and be reflown. On this test run the two side rockets returned to Earth as planned, but the middle booster ran out of fuel and crashed.**

**The payload, however, was successfully delivered into orbit and coasted around the Earth for six hours before the secondary stage engines fired, sending the roadster and its passenger into a highly elliptical orbit that extends just beyond Mars. NASA is tracking the car to ensure that it does not endanger any future space missions that may cross paths with it. Some planetary scientists are concerned that the roadster may one day crash into a planet or asteroid, as it was not created in a clean environment and could contaminate any potentially habitable environment. However, orbital predictions have found no risk for at least the next few centuries.**

**In the future, the Falcon Heavy will be capable of launching the equivalent of a double decker bus into the orbit of Mars. And because it is reusable it will only cost tens of millions of dollars to do so, rather than the billions of dollars it would cost launching one-use rockets, drastically reducing the price of spaceflight.**

**▸ See Comment, right**



**The Falcon Heavy should help drastically reduce the cost of spaceflight thanks to its reusable rockets. Well, *mostly* reusable...**

SPACE X x 2

## COMMENT
by Chris Lintott

Put a car in space and it shouldn't surprise anyone if it attracts the attention of astronomers.

Observatories tracked the Falcon Heavy's scarlet payload as it headed out into interplanetary space playing Bowie on repeat; the SOAR telescope in Chile measured periodic changes in brightness, and announced that the car is rotating once every 4.7589 minutes (plus or minus 0.36 seconds!).

My favourite work was led by Professor Hanno Rein, who tried to work out what will happen to the car on its elliptical orbit. It will have a close encounter with Earth in the year 2091 – I wonder if anyone will look out for it? – but much beyond that repeated planetary encounters make its path very difficult to predict.

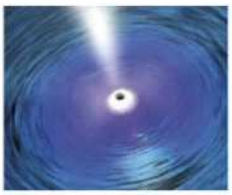
The best Hanno can do is work out that there is a 6 per cent chance the roadster will collide with Earth in the next million years, ending its mission as a spectacular meteor – all part of SpaceX's best-selling show.

CHRIS LINTOTT co-presents *The Sky at Night*

# NEWS IN BRIEF

## JWST NEARS COMPLETION

The James Webb Space Telescope (JWST) is almost complete. The optical assembly is now being combined with the science instruments for a 2019 launch. "The Webb Observatory, which is the work of thousands of scientists and engineers across the globe, will be carefully tested to ensure it is ready to launch," says Eric Smith, director of the JWST Program at NASA. "It will enable scientists to seek the first luminous objects in the Universe and search for signs of habitable planets."



## BIG BLACK HOLES FOUND

Some of the most massive black holes ever seen have been uncovered 3.5 billion lightyears away. They are estimated to be 10 billion times the mass of the Sun, making them ultramassive black holes. "Are they so big because they had a head start or because certain ideal conditions allowed them to grow more rapidly over billions of years? For the moment, there is no way for us to know," says Mar Mezcua from the Institute of Space Sciences in Spain, who took part in the study.

NORTHROP GRUMMAN, NASA, DIMITAR TODOROV/ALAMY STOCK PHOTO, C. KILPATRICK/UC SANTA CRUZ AND CARNEGIE INSTITUTION FOR SCIENCE/LAS CAMPANAS OBSERVATORY/CHILE, ICRAR X 3, TOMMY NAWRATIL/CCDGUIDE.COM, UA LUNAR AND PLANETARY LABORATORY, ESA/ATG MEDIALAB

# TRAPPIST-1 worlds COULD HAVE WATER

## The seven rocky planets have been under intense scrutiny

**The planets of TRAPPIST-1 could hold as much as 250 times more water than Earth's oceans according to their latest density measurements. Though the water would be frozen into ice sheets or in the form of water vapour on most of these planets, some of the worlds could potentially have liquid oceans.**

**The red dwarf star TRAPPIST-1 has interested scientists since the discovery that it was surrounded by seven Earth-mass, potentially rocky planets. Since then, astronomers have been studying the planetary system closely, trying to accurately measure the size and mass of the planets, in order to calculate their density.**

**"We now know more about TRAPPIST-1 than any other planetary system apart from our own," says Sean Carey, manager of Spitzer Science Centre at the California Institute of Technology. "The improved densities in our study dramatically refine our understanding of the nature of these mysterious worlds."**

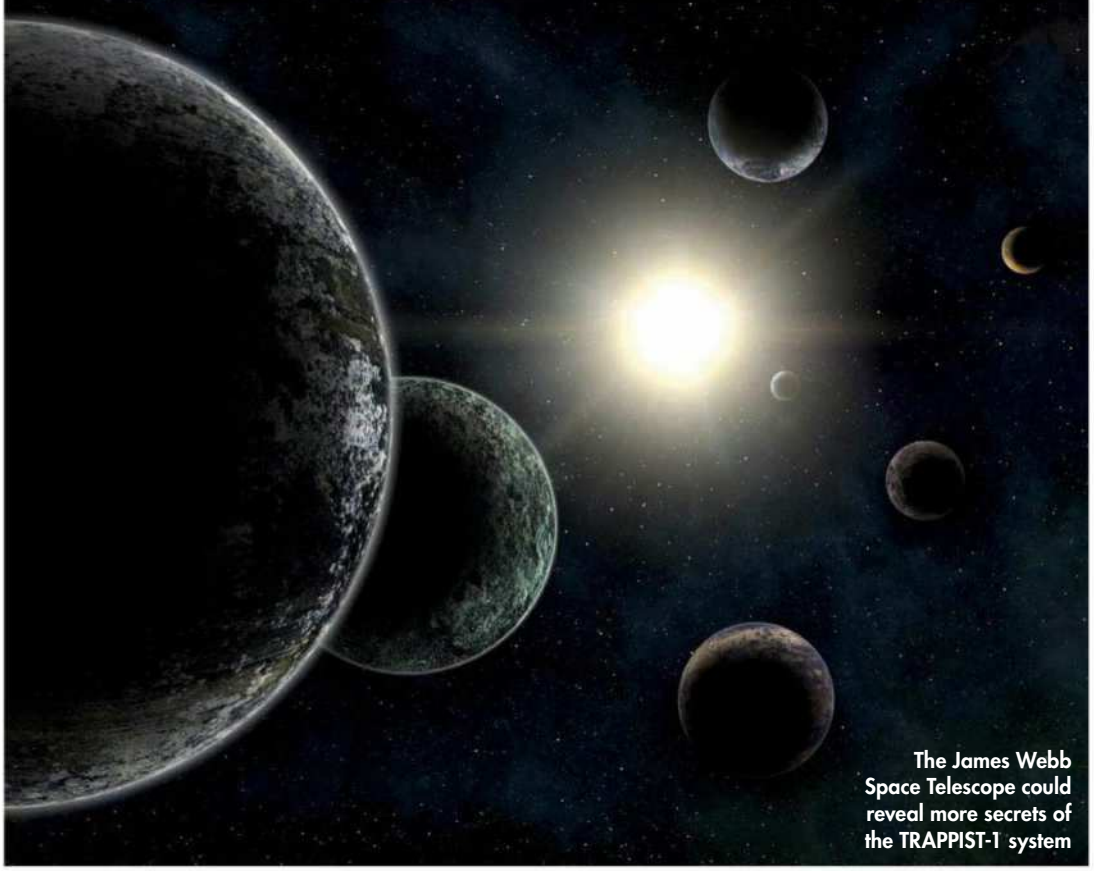
**By interpreting these densities, the planetary scientists were able to determine what these planets might look like.**

**The innermost planets, TRAPPIST-1b and c, both have rocky cores, though b has a thicker atmosphere. The third world, TRAPPIST-1d, is the lightest of the seven and is thought to have a layer of water, either an ocean or an ice sheet, and is surrounded by an envelope of volatile substances. The only planet denser than Earth is TRAPPIST-1e; astronomers suspect it may have an iron core but it doesn't appear to have an atmosphere, ice layer or ocean. TRAPPIST-1f, g and h are all so far away from the host star that water ice could exist on their surfaces. They may also have atmospheres, but would be unlikely to contain heavy gases such as carbon dioxide.**

**"It is interesting that the densest planets are not the ones that are the closest to the star, and that the colder planets cannot harbour thick atmospheres," says the University of Zurich's Caroline Dorn, who took part in the study.**

**Astronomers will have to wait until 2019, when the James Webb Space Telescope is due to launch, to really find out in more detail about what these planets are like.**

**www.jpl.nasa.gov**



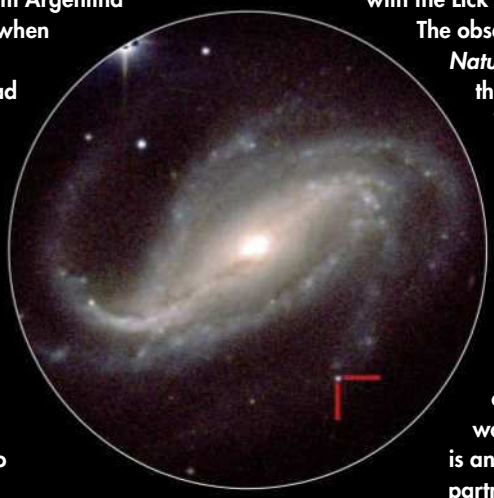
**The James Webb Space Telescope could reveal more secrets of the TRAPPIST-1 system**

# Amateur finds supernova

An amateur astronomer from Argentina who made history in 2016 when he captured the moment a supernova exploded has had his observations published. Víctor Buso made his serendipitous discovery while taking images of the spiral galaxy NGC-613 to test a new camera for his 16-inch telescope.

"Professional astronomers have long been searching for such an event," says Alex Filippenko from the University of California, Berkeley, who followed up the discovery with the Lick and Keck observatories. The observations, published in *Nature* in February, reveal that the blast was a Type IIb supernova, created by the explosion of a star that had lost its outer hydrogen.

"Observations of stars in the first moments they begin exploding provide information that cannot be directly obtained in any other way," says Filippenko. "This is an outstanding example of a partnership between amateur and professional astronomers."
**www.berkeley.edu**



▲ Capturing this image of a supernova was a one-in-100-million piece of luck

# Andromeda galaxy smaller than anticipated

## The Milky Way's 'bigger' brother may be more of a twin

The Andromeda Galaxy might not be as large as we thought, as a new method of measuring its size suggests that it is roughly the same mass as the Milky Way. The team behind the discovery measured the speeds of stars in Andromeda to find the escape velocity of the galaxy, which is determined by its mass.

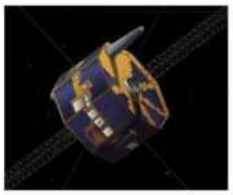
"By examining the orbits of high-speed stars, we discovered that this galaxy has far less dark matter than was previously thought, and only a third of that uncovered in previous observations," says Dr Prajwal R Kafle from the University of Western Australia who led the study.

Andromeda and the Milky Way are the two most prominent members of the Local Group of galaxies, and this finding will have big implications for our ideas about our nearest neighbours.

"It's really exciting that we've been able to come up with a new method and suddenly 50 years of collective understanding of the Local Group has been turned on its head," says Kafle.
**www.icrar.org**


► With Andromeda no longer considered the Milky Way's big brother, new simulations are required to predict what will happen when the two galaxies collide

# NEWS IN BRIEF



## RETURN OF THE SATELLITE

Astronomers have made contact with an aurora-investigating satellite long thought dead. Satellite hunter Scott Tilley picked up a transmission on 20 January 2018 and matched its position to NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), which lost contact with Earth in 2005. After tracking down the now obsolete technology needed to talk to IMAGE, NASA has ascertained it is healthy and is now trying to establish full contact.

## EXOMARS IN FINAL ORBIT

ESA's ExoMars orbiter is now ready to start 'sniffing' the Red Planet, looking for methane in Mars's atmosphere. The spacecraft entered the planet's orbit in October 2016, and has spent the time since aerobraking to bring it to within 200km of the planet's surface. Now it is in place, ExoMars will look for trace gases that make up less than one per cent of the atmosphere. Previous missions found signs of a seasonal release of methane, which may indicate some activity on the surface.

# CUTTING EDGE

**Our experts examine the hottest new research**

# NGC 7252: capturing a cosmic car crash

Observing the wreckage of a galactic pile-up could give astronomers clues to our own Galaxy's destiny

ESO

▲ **NGC 7252's oddly shaped tangle of stars, gas and dust, the result of the collision of two spiral galaxies**

NGC 7252 is a beautiful spiral of a galaxy in the constellation of Aquarius, its arms arranged in complex interlocking rings, speckled with bright clumps of newly formed, massive, blue stars; all of which is embedded in a ghostly halo of fainter material. It has long been thought that it owes this unusual appearance to a major merger, a car crash of a collision between two spirals, each rich in the gas that can fuel star formation.

This galaxy-changing event happened nearly on our doorstep, at a distance of 220 million lightyears, and is believed to have taken place only a billion years ago, which means that the galaxy has yet to have time to recover properly. In a Universe in which it's believed most big systems go through such major mergers every few billion years on average, studying a nearby example like NGC 7252 might tell us about how such galaxies form and evolve.

There is a big row in the field at the minute about how significant such mergers might be, and the simulators have already had a go at NGC 7252, predicting with a supercomputer how the collision of the two galaxies must have produced successive bursts of star formation.

There's no substitute for observation, though, and the authors of this paper, led by John R Weaver from St Andrews, have a powerful weapon in the form of an instrument called VIMOS, attached to the Very Large Telescope. VIMOS is an Integral Field Unit (IFU), one of a new breed of clever cameras that simultaneously provide a grid of spectra so that individual parts of a galaxy can be studied independently of each other. From each spectra, the properties and movements of gas and stars can be deduced.

The data is stunning, revealing a slowly rotating disc, slightly tilted from our point of view, with streams of gas leading away to the northeast and southwest. Unusually, though, some stars are rotating around the galaxy's longest axis, at right angles to the main disc, a sign that the merger that produced NGC 7252 is more complex than expected.

> "This major merger event happened nearly on our doorstep. Studying examples like this might tell us about how galaxies form and evolve"

Modelling the history of the galaxy reveals that increased rates of star formation started early, at its centre, and moved outwards as the merger progressed. This inside-out process – where the mutual gravitational attraction of colliding galaxies creates new stars – has been suspected, but has rarely been as cleanly detected as it is here. Things then quietened down ahead of the final merger, but the gas in the centre of the galaxy is now excited by star formation, still going strong at more than double the Milky Way's rate.

Even so, there is plenty of gas left; NGC 7252 could sustain its current rate of star formation for another five billion years. This would make its transition from blue star-forming galaxy to red merger relic an extremely slow one, unless some new process intervenes. Will it? As the authors point out, they can't predict the future. We can either wait a few billion years to watch the story play out, or take a close look at more distant systems, trying to work out how they compare to this marvellous wreck of a galaxy.

**CHRIS LINTOTT** is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project

**CHRIS LINTOTT** was reading… *History and Destiny of an Emerging Early-type Galaxy: New IFU Insights on the Major-merger Remnant NGC 7252* by John R Weaver, et al. **Read it online at https://arxiv.org/abs/1801.09691**

# Starlight's first glow detected

## Signs of the light from the earliest stars observed for the first time

The first stars in the Universe would have been massive and blue

For the first time, astronomers have detected the glow from when the earliest stars began to shine, 180 million years after the Big Bang.

These stars are too dim to be picked up directly by conventional telescopes. Instead, the team searched for the stars by looking for the imprint they left on the cosmic microwave background (CMB). The first stars were very bright in ultraviolet light, and this radiation interacted with the surrounding hydrogen molecules, causing them to absorb the photons that make up the CMB.

"You start seeing the hydrogen gas in silhouette at particular radio frequencies," says Alan Rodgers from MIT's Haystack Observatory, who took part in the study. "This is the first real signal that stars are starting to form, and starting to affect the medium around them."

**www.haystack.mit.edu/**

# Hot-Saturn's atmosphere unlocked

A UK-led team has released the most detailed study of an exoplanet's atmosphere ever performed. The planet, WASP-39b, orbits a Sun-like star 700 lightyears away and is roughly the same mass as Saturn but has a much tighter, closer orbit. The atmosphere contains three times more water than Saturn, suggesting that it formed further out then migrated inwards. A similar planetary shuffle is thought to have happened in our own Solar System.

"We need to look outward to help us understand our own Solar System," says Hannah Wakeford from the University of Exeter, who led the study. "Exoplanets are showing us that planet formation is more complicated and more confusing than we thought it was."

**www.exeter.ac.uk/**

▲ WASP-39b, which was discovered in 2011, has now been found to have three times as much water as Saturn

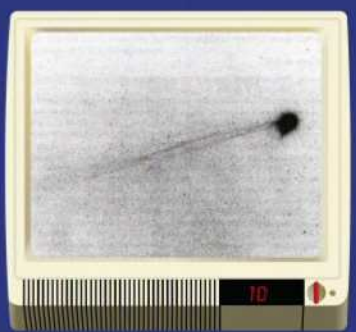
# **LOOKING BACK** THE SKY AT NIGHT

## 11 March 1990

**In the 11 March 1990 episode of *The Sky at Night*, Patrick Moore looked at the impending celestial visitor Comet Austin (1989c1). Discovered by New Zealander Rodney Austin on 6 December 1989, the comet's nucleus at first appeared to be around the size of Comet Halley and astronomers hoped it would be just as spectacular. However, as Patrick warned on the show, "It's always dangerous to make predictions, plus comets are unreliable things."**

**Comet Austin proved to be very much so. For the first few months, the comet brightened very quickly, but by early February, the rate at which it was brightening had slowed significantly. After it passed through perihelion on 9 April, the comet was six magnitudes weaker than had first been predicted.**

**So what had initially promised to be one of the most memorable celestial sights of the 20th century ended up being a footnote in cometary history.**



▲ Despite initial excitement, Comet Austin proved to be a damp squib

# NEWS IN **BRIEF**

### LUNAR XPRIZE CANCELLED

The Google Lunar XPrize of $30 million for the first private company to land a rover on the Moon will go unclaimed after having had its deadline extended each year since 2014. None of the teams can make the latest 31 March 2018 deadline. XPrize is looking for a new sponsor, but the competition has already inspired several new space companies to plan lunar missions. The five finalists are all expected to proceed with their moonshots even without the prize.

### MARTIAN CLAY NEEDS WARMTH

The climate of Mars may have gone through brief periods of warmth, according to the latest research from the SETI institute. There are numerous clay beds on Mars, which require warmer temperatures to form than are thought to have existed on the early planet. After studying similar clay on Earth, the team has revealed that such beds could form if there are occasional periods of warmer weather, perhaps caused by volcanic eruptions or small changes in the tilt of Mars's orbital axis.

N.R.FULLER/NATIONAL SCIENCE FOUNDATION, NASA/ESA/AND G. BACON (STSCI), ESO, GOOGLE LUNAR X PRIZE, NASA/JPL-CALTECH/ESA/UA

# CUTTING EDGE

**Our experts examine the hottest new research**

# Snowball Earths thaw faster with longer days

How long a frozen planet will take to defrost could depend on how long its days are

▲ **Slowly-rotating exoplanets may freeze and defrost with surprising regularity**

There have been several periods in Earth's history when the entire planet has frozen over. These so-called 'Snowball Earth' phases are triggered when the climate cools to such a degree that large ice sheets start extending far from the poles. The bright white surface of the ice reflects more sunlight back out into space than rock, causing the temperature to drop even further, until this literal snowball effect sees even the equator freezing over.

The planet would remain locked for evermore in this frosty state were it not for the saving grace of volcanism: the sealed surface experiences minimal erosion and so erupting carbon dioxide builds up in the atmosphere until the intensifying greenhouse effect suddenly lurches the planet back into a warmer, deglaciated state. It's almost as if the planetary climate has two extreme states between which it can occasionally – but suddenly – switch, and this has had significant implications for the evolution of life on Earth.

But what about on Earth-like extrasolar planets? Recent modelling studies found that an exo-Earth which is tidally locked to its star, so that one side is always facing its sun, doesn't experience these sudden switches into and out of snowball events; it shifts gradually between the two. Even a small increase in atmospheric carbon dioxide will cause the ice to thaw at the planet's warmest point – the 'subsolar point' where the sun is permanently directly overhead – exposing the darker surface beneath, allowing the planet to absorb more sunlight. This paves the way for a smooth transition back to a deglaciated state.

The big question, though, is what happens for planets with a day length somewhere in between Earth's rapid rotation and the very slow spin of tidally locked worlds? What about a planet that isn't perfectly tidally locked, but still has a slow rotation period of, say, a hundred or more Earth days?

That's exactly what Dorian Abbot and his colleagues at the University of Chicago have been using computer modelling of planetary climates to find out. They created a simple scenario of a planet without continents and an ocean of constant depth, as this allowed them to rapidly run huge numbers of different simulations. They found that exo-Earths rotating with a period of just a few tens of Earth days, but with similar levels of volcanic activity to us, would quickly be able to rescue themselves from a snowball state. The greater their day-length, the longer the period that the same patch of ice on the equator is heated by direct sunlight and so the less additional carbon dioxide is needed from other sources to initiate the deglaciation process. The Earth became stuck in its snowball phases for tens of millions of years, but such extrasolar planets could re-thaw themselves almost immediately.

> "Exo-Earths rotating with a period of just a few tens of Earth days would quickly rescue themselves from a snowball state"

Such snowball phases on Earth have been rare, last occurring 2.4 and 0.65 billion years ago. But what Abbot's simulations show is another possible outcome for extrasolar planets. If an exo-Earth has long days but also reduced levels of volcanic activity with resultingly slow rates of carbon dioxide release, its climate would perpetually swing back and forth between snowball and deglaciated states. If you could watch such a world in fast forward you'd see it rhythmically flash all white.

**LEWIS DARTNELL** is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

**LEWIS DARTNELL** was reading… *Decrease in hysteresis of planetary climate for planets with long solar days* by Dorian S Abbot and colleagues
**Read it online at https://arxiv.org/abs/1801.10551**

# The Super Eye for the night sky

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**CONCLUSION:**

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*Source: Marcus Schenk*

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## THE STARS A LITTLE NEARER

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Astroshop.co.uk

# "Dave had just flown all the way from Alpha Centauri."

"*Theakston's Best Bitter please,*" he asked the android behind the bar. Our hoverstools whooshed us to a table where our pints waited, golden as a Neptunian sunset. "*You know, they've been brewing this cask beer the same way for over 2,875 years,*" Dave said. "*Bet it still tastes just as good too,*" I replied. Dave was now in full flow. "*And they use the same mash tun from 1875. So every pint of cask Theakston's in the entire universe ever has come from just one mash tun, including everyone's in this bar now.*" I looked around the Time Traveller's Arms. Rick the Robot was nursing his pint and busy snacking on iron-filing flavour crisps. In the corner sat Artus Minor and his wife Debbie from Whitby. And across the room the Andromeda twins were playing six dimensional dominoes. "*What you are witnessing, my friend,*" Dave explained, "*is intergalactic harmony on a grand scale.*" His eyes were bright with belief. "*And it's all down to Theakstons and their 2,875 year old mash tun!*" Honestly, I really do sometimes wonder what planet Dave is on.

# "Boy, was he thirsty."

# What's on

Our pick of the best events from around the UK


## Edinburgh International Science Festival 2018

**Various venues, 31 March–15 April**

One of the UK's biggest science festivals returns to the Scottish capital for over two weeks of events. Join geoscientists from The University of Edinburgh to learn how they observe our planet from space; take a simulated trip into space to search for extraterrestrial life with Cosmos Planetarium; or take part in a workshop to build your own 'walking' rover.

The festival also features talks from some of the biggest names in science. Astronomers Dr Marek Kukula and Prof Gillian Wright look ahead to the launch of the James Webb Telescope; Dallas Campbell presents his top tips for journeying into the cosmos; and Prof Dame Jocelyn Bell Burnell tells the story of women in astronomy, past and present. Dr Niamh Shaw and *Great British Bake Off* finalist Andrew Smyth demonstrate the link between food and space travel; and Marcus Chown explores potential space-based careers, from Moon mining to becoming an alien cultural exchange officer.

Other workshops and lectures on offer include how to survive life-threatening situations in space; how to image the Sun with a six-month pinhole camera; astrophysicists' search for dark matter and dark energy; an astrophotography masterclass; and the latest in the search for life in the Universe.

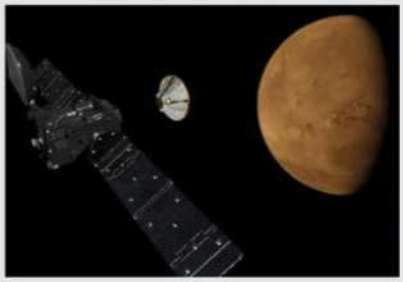
**www.sciencefestival.co.uk/festival**

EDINBURGH INTERNATIONAL SCIENCE FESTIVAL X 4, ESA/ATG MEDIALAB, BATTLESTEADS, SDSO

## BEHIND THE SCENES

### THE SKY AT NIGHT IN APRIL

BBC Four, **8 April,** 10pm (first repeat BBC Four, **12 April,** 7.30pm)*



Will the ExoMars Trace Gas Orbiter find signs of life in the Red Planet's atmosphere?

**MARS: RED AND DEAD?**

Maggie and Chris reveal the latest results from NASA's Curiosity and ESA's ExoMars TGO missions, which are attempting to find signs of life on Mars. Maggie finds out how the next lander heading to Mars will survive its hostile environment, and Chris talks to *The Martian* author Andy Weir.

***Check www.bbc.co.uk/skyatnight for subsequent repeat times***

## Astronomy at Battlesteads

**Battlesteads Hotel & Restaurant, Wark on Tyne, 7, 8 April, 8.30pm**

*BBC Sky at Night Magazine* contributor Steve Tonkin hosts a masterclass in binocular astronomy at Battlesteads Dark Sky Observatory. Find out 'Ten Ways the Universe Tries to Kill You' and how to search the skies with binoculars. This hands-on experience is suitable for ages 14 and over. Tickets are £32.50, £25 for concessions and £82.50 for families.

**www.battlesteads.com/observatory**

## The Life of Caroline Herschel

**Bath Royal Literary and Scientific Institution, Queen Square, Bath, 5 April, 7.30pm**

18th century astronomer Caroline Herschel discovered several comets and became the first woman to be awarded a Gold Medal from the Royal Astronomical Society. Astronomer Dr Emily Winterburn looks at Herschel's early career, and how she rose to prominence at a time when women's voices were often repressed in the scientific community. Admission is £4, £2 for students and members of the William Herschel Society.

**www.williamherschel.org.uk/events**

## Lyrid meteor shower

**Scottish Dark Sky Observatory, Dalmellington, 22 April, 9.30pm**

Make the most of this year's Lyrids by joining the Scottish Dark Sky Observatory for some meteor spotting on the northern edge of Galloway Forest Dark Sky Park. The event includes an introductory presentation and guided stargazing through the observatory's two large telescopes (weather permitting). Tickets are £15, £10 for concessions.

**www.scottishdarkskyobservatory.co.uk**

## MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.

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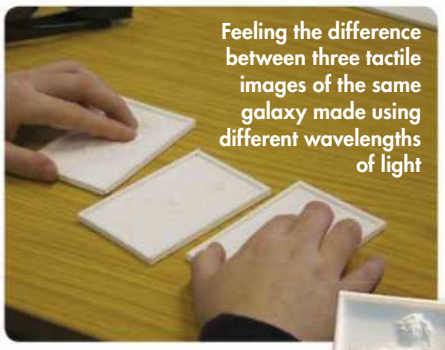
# A PASSION FOR SPACE

## with **Dr Jen Gupta**

## Vision impairment need be no barrier to studying astronomy thanks to some innovative new projects

▲ **Professor Karen Masters shows one of the tactile galaxies to Brian Anderson at an event**



**Feeling the difference between three tactile images of the same galaxy made using different wavelengths of light**

► **Blue, red and infrared tactile images of M51 with their visual-image counterparts shown underneath**

When most people think of astronomy, they think of staring up at the stars in the night sky, maybe putting their eye to a telescope or looking at stunning images from observatories like the Hubble Space Telescope. Despite the fact that few (if any) professional astronomers these days would ever need to look through a telescope as part of their research, astronomy is still perceived as primarily a visual science. This perception means that people who are blind or vision impaired can easily feel excluded from the subject.

There have been notable exceptions. In the movie *Contact*, the blind astronomer Kent Clark was based on Dr Kent Cullers, reportedly the world's first totally blind physicist who spent his career working on SETI (the Search for Extra Terrestrial Intelligence). After losing her sight early in her career, astrophysicist Dr Wanda Diaz Merced turned to audio representations of astrophysical data: so-called 'sonification'. A colleague of mine, Dr Nic Bonne, is a blind astrophysicist working on ways to explain his galaxy evolution research to a vision-impaired audience using tactile aids. However, these examples are scarce, and people with vision impairments remain severely underrepresented in astronomy.

## Keeping in touch

The Tactile Universe is our attempt to change this. Led by Dr Bonne and Dr Coleman Krawczyk at the University of Portsmouth, we are creating 3D-printed tactile images of galaxies so that people can feel the shapes of galaxies without the need to see them. Different types of stars will be different colours depending on their temperatures, so by making separate 3D models of the image of a galaxy taken through a red filter and a blue filter, we can start to explain some of the science of galaxy formation and evolution.

We've been testing these tactile galaxies in local schools and have already seen the impact of this work. One primary school pupil said, "Working with Dr Nic made me realise I could do science at university and maybe even get a job as a scientist."

And it's not just us engaging with this community. A Touch of the Universe, AstroSense and Touching Space are just some of the other projects, in the UK and around the world, that are opening up astronomy to people with vision impairments. In December 2017 we organised a meeting at the Royal Astronomical Society in London to gather together people working in this area, hopefully the first of many.

It's easy to forget that nearly all of us need a helping hand to enhance our view of the Universe, whether that's using binoculars, a telescope or image processing software to enhance astrophotography. By collaborating with these other projects, we hope to truly make astronomy open and accessible to all. S

Astrophysicist Dr Jen Gupta is a regular contributor on *The Sky at Night*

Maggie Aderin-Pocock is on holiday

JEN GUPTA/TACTILE UNIVERSE X 2, COLEMAN KRAWCZYK/TACTILE UNIVERSE

## JON CULSHAW'S

# EXOPLANET EXCURSIONS

### Jon journeys to a brooding brown dwarf 10 times larger than Jupiter

Sixty lightyears from Earth, in the constellation of Mensa, lies the yellow dwarf star Pi (π) Mensae. Named after Table Mountain in South Africa, Mensa is a faint constellation too southerly to be visible from UK skies. However, I'm piloting the The Perihelion there in the hope of witnessing a most impressive and unusual astronomical sight.

Pi Mensae shares many similarities to our Sun, being a stable yellow dwarf. It is much more youthful than the Sun, though – 730 million years younger. When our parent star was this age, the Earth was at a much more primordial stage. Its oceans were populated by Placozoa, odd plate-like organisms about a millimetre across, which are the simplest form of life yet discovered.

The stability of Pi Mensae led to it being placed on the list of targets for NASA's abandoned Terrestrial Planet Finder project, and it's the fascinating planet Pi Mensae b that's going to be the destination of our visit this time.

This world is over 10 times the size of Jupiter, so it's most likely a brown dwarf. It takes just under six of our years to complete a dramatically elliptical orbit. At its most distant, it lies 3.4 AU from its parent star and it comes as close as 2.6 AU, taking it on a trip straight through the star's habitable zone.

Steering The Perihelion to this zone I discover a Venus-sized moon orbiting Pi Mensae b. The surface is cracked and fissured like Death Valley on Earth. Its texture reminds me of the sooty, heat-hewn clay background of a Victorian fireplace. The sky is black and hanging majestically at its centre is the brooding, mysterious brown dwarf Pi Mensae b. What a stunning image it is, like a bronze-filtered spotlight shining a soft, shimmering beam on a giant copper gong. Other moons move across its surface, visible as black dots in transit, some disc-shaped, some irregular ovals similar to Phobos or Deimos.

I move the Perihelion to a specific position to observe an exquisite cosmic phenomenon I've always wanted to see: a yellow star, like our Sun, being totally eclipsed by a brown dwarf. The partial phases have an unusually charged sense of drama, as the incandescent gold of Pi Mensae is gradually obscured by the dominating disc of a brown dwarf the colour of backlit treacle. What follows is a desperately intriguing totality. The stellar corona around Pi Mensae glows with platinum streaks, surrounding not a solid black circle but a luminously soft glowing brown dwarf. It is utterly surreal, like a colossal sunflower in space.

Arthur C Clarke famously said, "The Universe is not only stranger than we imagine, it is stranger than we *can* imagine," and in my mind I imagine his voice saying, "See what I mean?" as I observe this astonishingly unusual sight.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

# Interactive

EMAILS ◢ LETTERS ◢ TWEETS ◢ FACEBOOK

Email us at **inbox@skyatnightmagazine.com**


**This month's top prize: four Philip's books**

PHILIP'S

**The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2018 Stargazing*.**

## Tales from THE EYEPIECE

**Stories and strange tales from the world of amateur astronomy by Jonathan Powell**

From various observing sessions and meetings over the years, I've learned that certain sky sights feature in a sort of 'amateur astronomers' bucket list', dictated by a beginner's craving to increase their portfolio of captured phenomena as they learn to walk, then run.

It starts with the craters of the Moon, then the moons of Jupiter and Saturn's ring system, before moving on to the Orion Nebula and a gradual push outwards to find ever more distant and obscure objects.

And yet there remain many inspiring targets back here on Earth. One of the first and most defining moments I'll never forget was a simple sunrise after watching a meteor shower fade away into the dawn sky. Quite humbling in its own right, and a definite must-see.

**Jonathan Powell is the astronomy correspondent for the *South Wales Argus***

MESSAGE OF THE MONTH

## Christmas crescent

Both my seven-year-old son Kush and I have been looking to hunt down a slim crescent Moon. On the morning of 16 December 2017 we hit the jackpot. We rose early and around 7.15am Kush spotted the Moon emerging from behind a nearby house. He was super excited when he saw it through the very basic scope I'd bought from Lidl. We took this picture using my Samsung Galaxy S8+ attached to the scope's 32mm Plössl eyepiece. I helped Kush use the settings on the phone's camera to reduce the ISO and shutter speed to capture a slim, 3.5 per cent-lit waning crescent Moon.

**Darshna Ladva, via email**

*A great early morning session, Darshna.* ***– Ed***

**▲ "Hi Ho Silver Lining" – the thinnest of crescents captured on a mobile phone**

**We're all made of stardust, so how about this for recycling?**

## Folding space

Thought I'd share my idea for making good use of my out-of-date monthly stargazing guides: I've turned them into a modular origami constellation star.

**Alice Hanney, via email**

*Ingenious, Alice! Origami's very useful for spacecraft engineers, helping them find efficient ways of folding solar panels.* ***– Ed***

## Tweets

**Paul Hayday**
@Mirrorlessview • Feb 19
Jupiter rising in the Brecon Beacons #WexMondays #Sharemondays2018 #sharemonday

## Intensifying Newton

I was interested to read your article on the 50th anniversary of the Isaac Newton Telescope ('A second chance at first light', December 2017 issue). In the late 1960s I worked at Marconi Instruments, helping with the experiments that paired a Marconi Image Intensifier with the Isaac Newton Telescope to increase its sensitivity. One night in June 1969, we set up the intensifier with the telescope, enabling the astronomers to enhance the image on the telescope by reducing the noise. I remember that operating the system in the middle of the night was an experience like nothing else. The enthusiasm of everyone involved as they saw the dramatic results was infectious.
**Chris Moore, via email**

*Wonderful to hear your memories of working with the Isaac Newton Telescope when it was at Herstmonceux, Chris.* ***– Ed***

## Address to a Moon

Saturday 27 January saw an unusual astronomy event take place at the Abriachan Community Forest near Loch Ness. Dubbed 'Lunar Burns Night', it was a celebration of astronomy and the life of Scotland's famous bard, Robert Burns, who was home schooled in mathematics and astronomy by his tutor John Murdoch. The evening combined Moon watching, a talk from astronomer Stephen Mackintosh, a Haggis address and hands-on lunar experiments for the young ones. It was very well received.
**Stephen Mackintosh, via email**

*What a fantastic way to pay homage to the "great chieftain o the puddin' race", Stephen. Readers can lean more about stargazing events at Abriachan Forest at* ***modulouniverse.com – Ed***

## Tweets

**David Forknall**
@habrokimaging • Feb 14
Last night at Ribblehead Viaduct. 1st attempt at star trails! @BBCNews @yorkshirepost @yorkdalesguides @yorkshire_dales @NationalRailP @letouryorkshire @BBCRadMac @ProfBrianCox @marksmcneill @skyatnightmag @AstronomyMag #Astrophotography #nightsky #samyang #canon #manfrotto

## SOCIETY in focus

**▲ On 23 February, the clouds parted in Liverpool to reveal some great lunar views**

Liverpool's Astronomical Society's (LAS) 'Sidewalk Event' in February was held at the Alt Centre in Hightown, Merseyside. Members and newcomers met around 6.30pm and good weather early on allowed us to observe the occultation of Aldebaran. Despite increasing cloud cover, our strategy of arranging the event to tie in with the first quarter lunar phase paid off: we managed to get some splendid views of the Moon through intermittent gaps in the cloud, along with Aldebaran and Castor.

LAS member Geoff Regan then gave a well-received talk on a range of subjects, which was followed by a question and answer session on such topics as whether a white dwarf star can become a black dwarf, what the upcoming James Webb Telescope will be used for and which are the best telescopes for beginners.

As well as sidewalk observing during the winter months, Liverpool Astronomical Society meets every Wednesday at 7pm, at the LAS Leighton Observatory, Pex Hill near Widnes, and holds monthly lectures at the Liverpool Quaker House. The society also runs outreach events, open days, solar days, telescope workshops and stands at various events. Visit **www.liverpoolas.org** for more information.

**Ken Sharples is a member of the Liverpool Astronomical Society**

## Meanwhile on FACEBOOK...

**WE ASKED: Do you have any problems with light pollution? Do you have any tips for mitigating the effects? (See page 42)**

**Natalie Penwill**
I used to have a great sky until part of the open field area behind my house was bought out by a large car company as a form of storage facility. It's basically a big parking lot with massive lights that cause so much sky glow it's unbelievable! Unfortunately, for security reasons they need these lights and I am still able to see a lot of stars at night (just not how I used to).

**Simon Whitfield**
A neighbour's security light. Had a chat and it turned out their young son was turning on all the lights and they didn't know... the light has been off ever since.

**Andy Burns**
Make sure lighting issues or concerns are highlighted at the planning stage. Some new projects around Wiltshire are well lit (Paxmead and the south of Trowbridge), others fall through the net (like military housing and industrial units).

**Pennie Ley**
Our council has been installing new street lights that are so bright you would think it's almost daytime still.

**David Jones**
It doesn't bother me – when the light pollution clears it's too cloudy to see anything.

**Colin Anderson**
These new LED lights might only shine downwards, but they are blinding! Catch one in your eyeline and your night vision's ruined.

**Alan Bickerstaff**
Our council trialled turning off streetlights about two years ago. The local crime rate wasn't high anyway, but it actually dropped after the trial, which became permanent.

**Diana Lynn**
Too many buildings not enough sky.

**Brendan Scoular**
A few years back I politely asked my neighbour if it was necessary to have their outside light automatically switch off at 2:30am. They agreed and it now goes off at midnight. Luckily, I'm in my element at such a time and the night sky is more enjoyable.

**Mike Cooper**
Live in the countryside then invite your stargazer mates over. Pure black skies!

**Danny Astro Kenealy**
I gave up observing from my garden and focused on widefield astrophotography from more remote places I can carry my gear to.

BBC

# Sky at Night MAGAZINE

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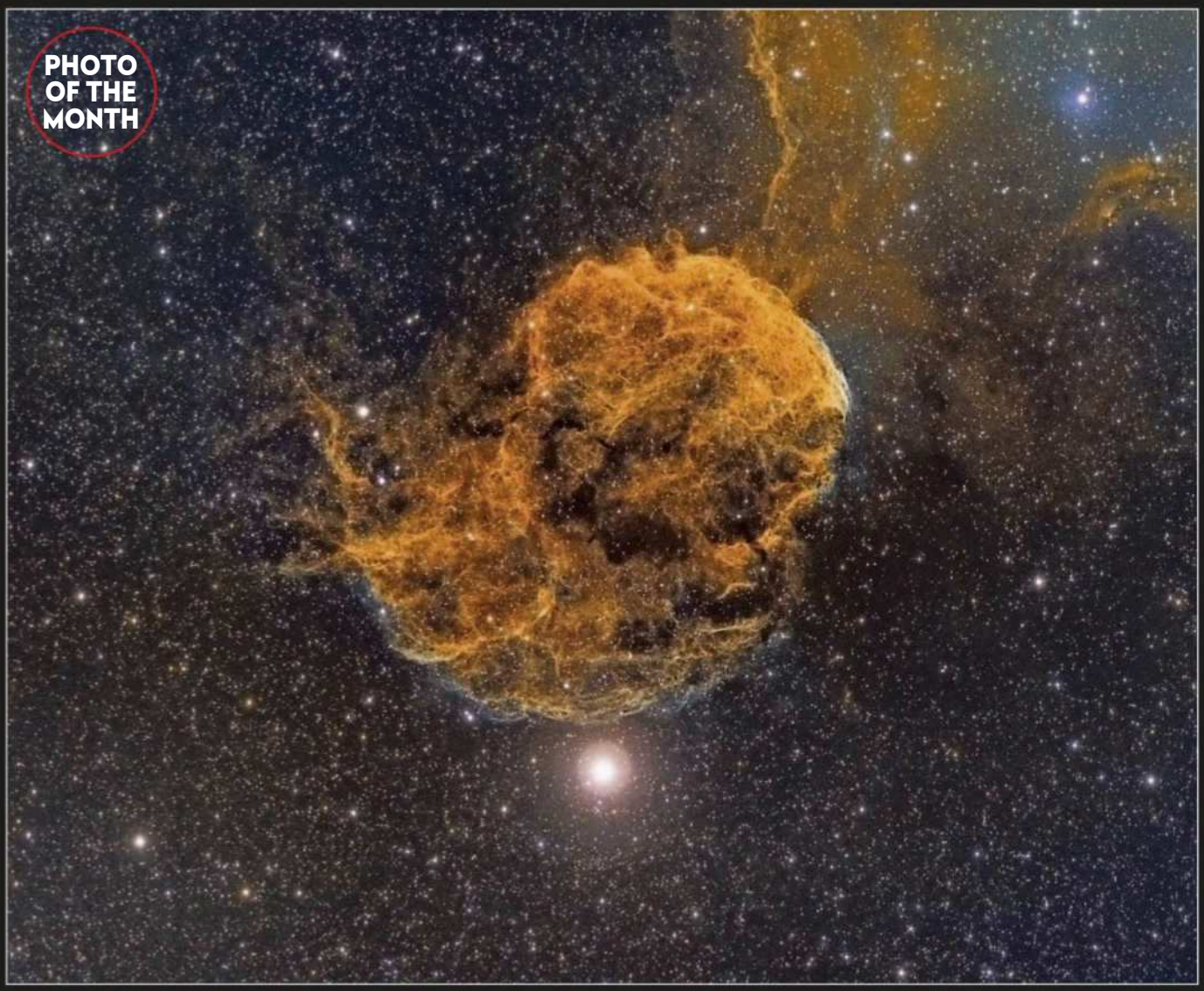
# Sky at Night MAGAZINE

# Hotshots

This month's pick of your very best astrophotos

**YOUR BONUS CONTENT**

A gallery containing these and more of your stunning images




## ▲ The Jellyfish Nebula

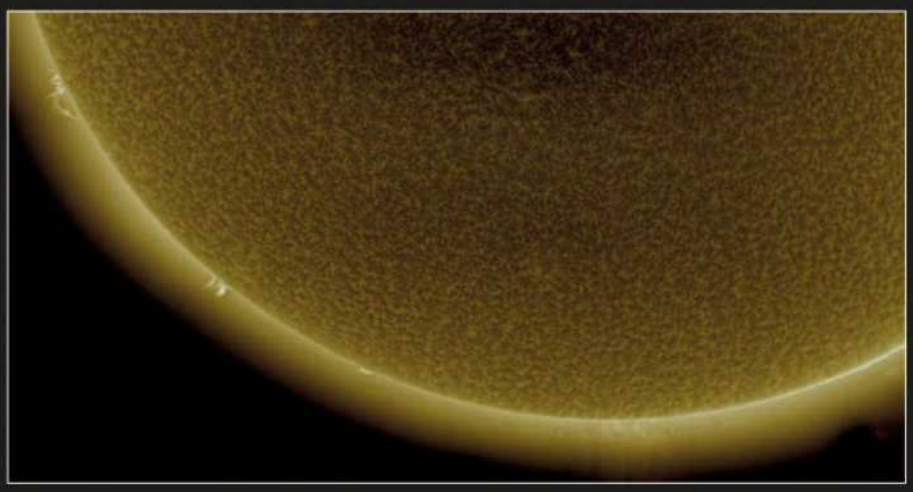
MARTIN BAKER, 25 NOVEMBER 2017 & 18 JANUARY 2018, BERKSHIRE

**Martin says:** "I took a test shot of this nebula a year ago and thought it looked amazing, so had to revisit it. Moon-glow at the start of November washed out my initial OIII data and it wasn't until the end of the month that I could get any more. On my first attempt at processing, I flattened the background too much and lost most of the nebulosity. I had another go, trying to lift the background a little without burning out the highlights. I'm happier with this version."

**Equipment:** Trius-SX694 CCD camera, William Optics Megrez 72mm doublet apo refractor, Sky-Watcher NEQ6 Pro SynScan mount.

***BBC Sky at Night Magazine* says:** "A crisp, clear nebula astrophoto is hard to beat, and this one fits the bill. Martin has captured a great image in which all the components combine to make an interesting spectacle, from bright star Eta (η) Geminorum below the Jellyfish's 'tentacles' to the beautiful, glowing emission nebula Sharpless 249 at top right."

**About Martin:** "I've had a love of astronomy since I was young, but I only got myself a scope in the last six years. As aviation photography is my other great passion, I started imaging from the offset. I really love narrowband results best, because local light pollution makes RGB hard work. It's amazing that you can target an object that you can't see through an eyepiece and end up with an image. Mrs B (my wife) thinks that the image looks more like a puffer fish than a jellyfish!"



## ▲ The Sun

FERNANDO OLIVEIRA DE MENEZES, BRAZIL, 19 JANUARY 2018

Fernando says: "The difficulty with capturing these images is the effect that high temperatures have on the focus of the telescope, along with burns in the tube and the cost of quality solar equipment! Solar imaging is a passion without limits. The Sun behaves differently throughout the day, creating wonderfully varied images."

Equipment: ZWO ASI174MM mono camera, TS Photoline 80mm triplet apo refractor, Daystar QUARK Ha eyepiece.

## ▲ Aurora

GILL WILLIAMS, YLLÄS, FINLAND, 19 JANUARY 2018

Gill says: "I go out to the Arctic Circle every year in January, staying in Äkäslompolo next to a very large frozen lake, which is ideal for looking at aurorae. As I walked out onto the lake the sky erupted; my first few shots were ruined because I was shaking with excitement!"

Equipment: Canon EOS 6D DSLR camera, Samyang 14mm lens.

## ▼ The Rosette Nebula

TONY KING, WOKING,
14 & 16 DECEMBER 2017

Tony says: "Imaging is always a challenge here in the UK because of the unpredictable weather, so achieving this completed image was very satisfying. I'd like to get some more data to enhance the image further, but will have to wait until next season now."

Equipment: QSI 683 CCD camera, TS Photoline 80mm triplet apo refractor, Sky-Watcher NEQ6 Pro SynScan mount.

## ▼ Bode's Galaxy

MARK SHELTON, BIRMINGHAM,
6-7 JANUARY 2018

Mark says: "I've been imaging for a few years but light pollution is my enemy, being located only a few miles from Birmingham Airport. This has necessitated lots more pictures to even out the sky background. I will be trying a light pollution reduction (LPR) filter shortly to see if this helps."

Equipment: QHY168C camera, Celestron C14 Schmidt-Cassegrain.

# Splendours of SPRING

## AN IMAGING AND OBSERVING SPECIAL

Astronomer **Will Gater** presents a selection of projects that will see you through spring and into the lighter summer months

As the twilight descends at this time of year, the icy nights of winter begin to slip from memory and the likes of Orion and Taurus sink toward the western horizon. And just as the stone-cold earth warms and new life bursts forth in the spring sunshine, so the night skies of April present us with a fresh array of astronomical sights to behold. In this piece we're going to look at just a few of these: a modest sampling of the wonderful targets afforded by the great fields of galaxies in Leo, Virgo and Coma Berenices; and the magnificent globular clusters strewn across Boötes, Hercules and beyond. There are six projects in total here, providing a mix of challenges across the fields of observational astronomy, imaging and even sketching. And if after all of this you still want more, be sure to explore the Sky Guide (on page 49) where you'll find information about some of spring's other celestial splendours. ▸

**ABOUT THE WRITER**
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com.

The three spiral galaxies of the Leo Triplet: NGC 3628 (far left), M66 (far right) and M65 (top)

Melotte 111 contains about 50 stars spread over 6 degrees of sky

# Marvel at Melotte 111

**Difficulty level: Beginner**

It's fair to say that many of spring's finest celestial splendours need a good telescope to see them in their glory, or at all. But there's one conspicuous exception to this rule – the beautiful grouping of stars classified as Melotte 111. From most sites free from the harshest levels of light pollution this stellar gathering is easily visible to the naked eye in the constellation of Coma Berenices, nestled between the bright stars of Leo and Boötes to the east. Melotte 111 is a superb target for binoculars with their very wide fields of view; it's a particularly dazzling sight in a good pair of 10x50s or 15x70s from a dark-sky site, with the glittering stars sparkling away against the inky black. It's a wonderful thing to set eyes on and proof that you don't always need a huge, expensive telescope to enjoy some of the night sky's real treasures.

# See Algieba's companion

**Difficulty level: Beginner to intermediate**

Even if the Moon is up, or a little light pollution blights your viewing site, observing multiple star systems can be a fun way to challenge your stargazing skills, notwithstanding the fact that many are striking sights in the eyepiece. The spring skies contain a fine double star in the form of Algieba (Gamma (γ) Leonis) in Leo. To find it, first identify the famous backwards question mark that forms the head and mane of Leo, with Regulus (Alpha (α) Leonis) at its base. From Regulus follow the question mark up to where it begins to 'curve' east at Eta (η) Leonis. Algieba is then the next bright star on the curve. Through a medium aperture telescope with around 150x magnification you should be able to clearly see its fainter companion. Observers have noted a yellowish tint to both stars. The illustration to the right is based on a sketch made with an 8-inch telescope.

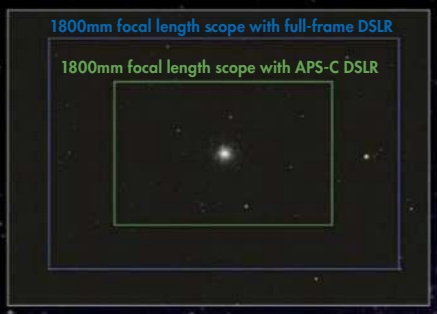
WILL GATER X 8

▲ **Algieba's two stars are only 17 times the Earth-Sun distance apart, separated by 4 arcseconds on the sky**

# Snap a spring globular cluster

**Difficulty level: Intermediate**

For many amateur astronomers spring is synonymous with galaxy hunting, but it's also a great time of year to go in search of some of the most striking globular clusters in the night skies of the northern hemisphere. From M53 in Coma Berenices to nearby M3 and the superlative M92 and M13 in Hercules, these striking, densely packed balls of myriad stars are enthralling imaging targets. In this short guide we're going to look at how to capture a glorious spring globular on camera; we're going to focus on shooting with a DSLR camera, telescope and tracking mount – though much of the advice here also applies to imaging with a CCD camera too.




## Step 1
### Getting up close

Because it's the multitude of pinpoint stars in and around their comfort centres that gives globular clusters much of their striking appearance, they look spectacular when imaged with long focal length telescopes. This requires a mount capable of accurate tracking, or one whose motion is corrected by auto-guiding technology. Alternatively, you can try taking shorter exposures at higher ISO levels to compensate for any lack of tracking accuracy over short timescales. If you need a 'closer-in' shot, some Barlow lenses and Powermates can be attached to a DSLR, thereby increasing your setup's effective focal length.

## Step 2
### Focus, then focus again

Once you have your equipment set up, focus the view through your DSLR using a bright star, like Arcturus (Alpha (α) Boötis), and a live-preview screen if your camera has one. It is well worth investing in a Bahtinov mask for this. Once placed over the front aperture or opening of a telescope this clever invention creates a set of diffraction spikes on bright stars, which only becomes symmetrical when perfect focus has been reached. This is vital when photographing globular clusters at high resolution as even a slight soft focus on an image of a mass of point sources is very noticeable.


## Step 3
### Framing, exposure and 'subs' capture

When you've got the image focused, slew the scope over to your chosen cluster. Ideally it shouldn't be too far from the bright star that you focused on in order to minimise the risk of the focuser and attached DSLR slipping out of focus as the setup turns to its new pointing position. Frame the globular to your satisfaction and take test shots to see what exposure length gives you a good amount of detail without the background sky 'fogging up' with light pollution; when you've found it capture at least 15-20 sub-exposures.

## Step 4
### Capturing flat fields and dark frames for calibration purposes

Now you need to collect some basic calibration data. Without adjusting your setup, wrap a white T-shirt or pillowcase taut over the scope's main aperture (avoiding touching any optics); light the fabric with a torch and capture 10-15 images with the DSLR in auto-exposure mode. These will create a master flat field that your processing software can later use to remove annoyances like dust mote 'shadows'. Next, place the dust cover on your scope and take 15-20 exposures of the same length as your sub-exposures; these will make a master dark frame that can be used to remove noise from your subs.

## Step 5
### Flat field and dark frame subtraction and stacking

With your DSLR photos downloaded onto your computer you now need to calibrate and stack them. If you've been shooting in RAW, which we would recommend, you may find this process easier – and gives better results – if you batch-convert your RAW files into TIFF files. There are numerous image-processing programmes that can calibrate and stack your data for you, but if you're new to astrophotography a good place to start is the free DeepSkyStacker (http://deepskystacker.free.fr/english/index.html) which can do it automatically once you've loaded your sub-exposures, flat fields and dark frames.

## Step 6
### And finally, processing and sharpening

Load the image – ideally an uncompressed TIFF or PNG file – produced by your astronomical stacking software into image-processing software such as *Photoshop* or *GIMP*. Tweak the colour balance if needed using the sliders for each individual colour channel in the Levels tool. To improve contrast, use the Curves tool but avoid darkening the image so much that a solid black background swallows up the fainter stars in the globular cluster's periphery. A small amount of sharpening can make globulars 'pop', but be careful not to give the stars dark haloes through over-sharpening.

▲ A sketch of M13, with gentle stippling recreating the globular cluster

▲ This sketch of M105 was originally black on white, but now inverted

# Sketch a spring deep-sky object

**Difficulty level: Beginner and up**

Exploring the spring night skies through the eyepiece of a telescope can be a magical experience as you hunt down ghostly galaxies and bright globular clusters with their exquisite granular forms. Astrophotos can capture the special qualities of these objects, providing spectacular, detailed views the likes of which our eyes could never see. But even in this age of CCD cameras and digital photography, there's still something to be said for simply sketching what you see through your eyepiece with an old-fashioned pencil.

Not only can sketching be a fun way to record what you've seen for your own memories, but it can also be useful for giving other amateur astronomers – particularly those just starting out – an indication of the sort of thing they can expect to see through equipment comparable to your own. This is especially true of the numerous faint galaxies scattered across the spring skies, which often appear in long-exposure astro images as shining swathes of light festooned with intricate details, when, in fact, the view through the eyepiece of a modest telescope is usually quite different.

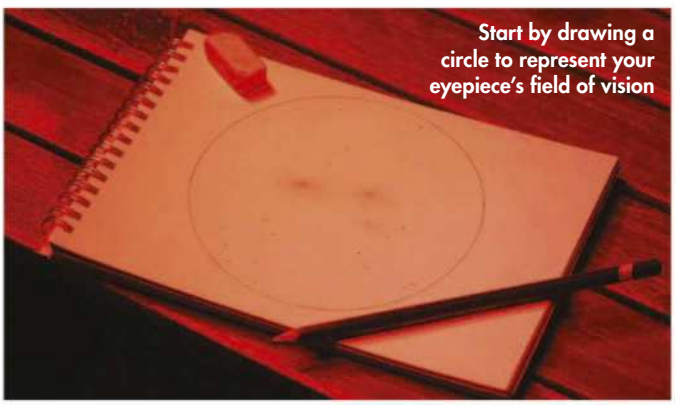
Sketching, at its most basic, requires some paper, a good pencil and something to rest on while you draw at the eyepiece. If it's something you think you'll enjoy doing often you can invest in a good-quality artist's sketch pad with heavyweight paper, because regular paper is likely to wrinkle during long sketching sessions outside. And as for pencils, you can usually execute most astronomical sketching techniques with just a good-quality 2B pencil. A decent eraser is handy, too.

Before sketching you should allow your eyes to become fully dark-adapted and, if possible, use a really dim, red, light-source – like a head torch covered in red acetate or red sweet wrappers – to draw by.

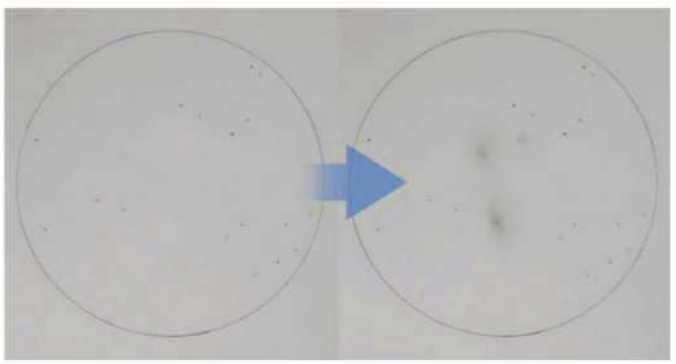
There are plenty of spring objects that make good targets for sketching, from any of the bright globular clusters we mentioned in the first project to brighter galaxies like M64 in Coma Berenices and the pairing of M65 and M66 in Leo.

To begin, draw a circle on your paper to represent the edge of your eyepiece's field of view. Once observing at the telescope, start by marking the positions of the brighter – then fainter – stars in the field of view, paying particular attention to the relative distances and angles between them. When you have the star field in place, begin sketching in your chosen deep-sky target. For galaxies use the side of the pencil lead to gently add graphite to the paper, blending and smudging with your fingertip to produce a fuzzy appearance if necessary. For globular clusters, gentle stippling can be an effective way to render the myriad stars at their cores.

Remember to draw 'inverted'; the dark pencil marks on the paper represent where you see light in the eyepiece. You can scan the sketch later and invert it in image-processing software, making your drawing look like the view in the eyepiece.



Start by drawing a circle to represent your eyepiece's field of vision



▲ First map out the major stars, then add in your deep sky objects

WILL GATER X 5, MARTIN RUSTERHOLZ/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM

# Track down a swarm of galaxies

**Difficulty level: Intermediate**

The spring skies abound with fascinating telescopic sights, but few are more enthralling than the galaxies that lie scattered across the constellations of Virgo, Leo and Coma Berenices. In places – the region between the stars Denebola (Beta (β) Leonis) and Vindemiatrix (Epsilon (ε) Virginis) being a great example – these galaxies swarm in truly remarkable numbers.

Indeed in some spots the density of (relatively) bright galaxies is such that it's possible to spy the faint fuzzy forms of several of them, all in the field of view of a medium-to-large aperture telescope. Tracking down some of these impressive galactic groupings and seeing them with your own eyes can be a wonderfully rewarding and humbling experience, especially when you consider the mindboggling scale and distances of what's on show in the eyepiece.

Perhaps the most striking collection of galaxies in the spring skies are those that appear close to the elliptical galaxies M86 and M84 in the constellation of Virgo. These two galaxies sit at the head of a tadpole-shaped grouping of galaxies known as Markarian's Chain, whose arcing 'tail' heads roughly northeast over the border into Coma Berenices. Another fine target for a larger aperture instrument is the striking galaxy trio of M105, NGC 3384 and NGC 3389, which is located just over a degree and a half away from Kappa (κ) Leonis in Leo.

If you're new to galaxy observing, remember to allow your eyes at least 30 minutes to an hour to adapt to the darkness prior to viewing through the eyepiece. And when looking through the telescope don't stare directly at your target; instead use 'averted vision' where you direct your gaze slightly away from the galaxy, allowing its faint light to fall on the more sensitive parts of your retina.

▲ **The trio of galaxies NGC 3389 (bottom left), NGC 3384 (top) and M105 (right) can be found a sneeze away from Leo's nose**

▲ **M86 and M84 (far right) are at one end of Markarian's Chain, while its other end stretches to the borders of Coma Berenices**

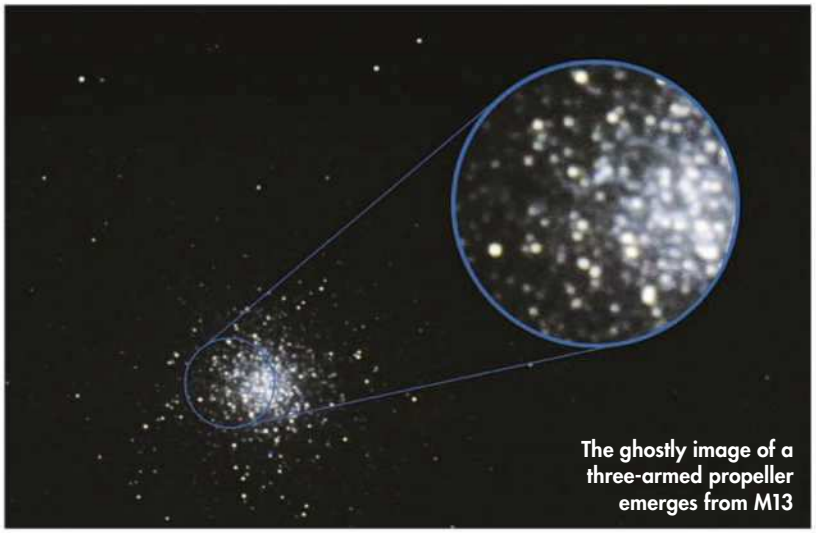
# Observe M13's 'propeller'

**Difficulty level: Beginner to intermediate**

The globular cluster M13 in the constellation of Hercules is easily the finest example of its kind in the night skies of the northern hemisphere. In a modest telescope of around six to eight inches it appears as a ball-shaped, huddled mass of countless tiny points of light.

For our final project in this article we're going to look for a particular feature in this beautiful cluster. In M13's southeastern corner the arrangement of stars along our line of sight is such that there is what looks like the (slightly transparent) silhouette of a three-bladed 'propeller' overlaid on the granular texture of the cluster.

If you struggle to see this feature try using averted vision, or observing from a site away from light pollution. Or, if it's a larger instrument you need, why not visit your local astronomical society on an observing evening when they may have larger scopes on hand to help you catch sight of this intriguing cosmic curiosity.



**The ghostly image of a three-armed propeller emerges from M13**

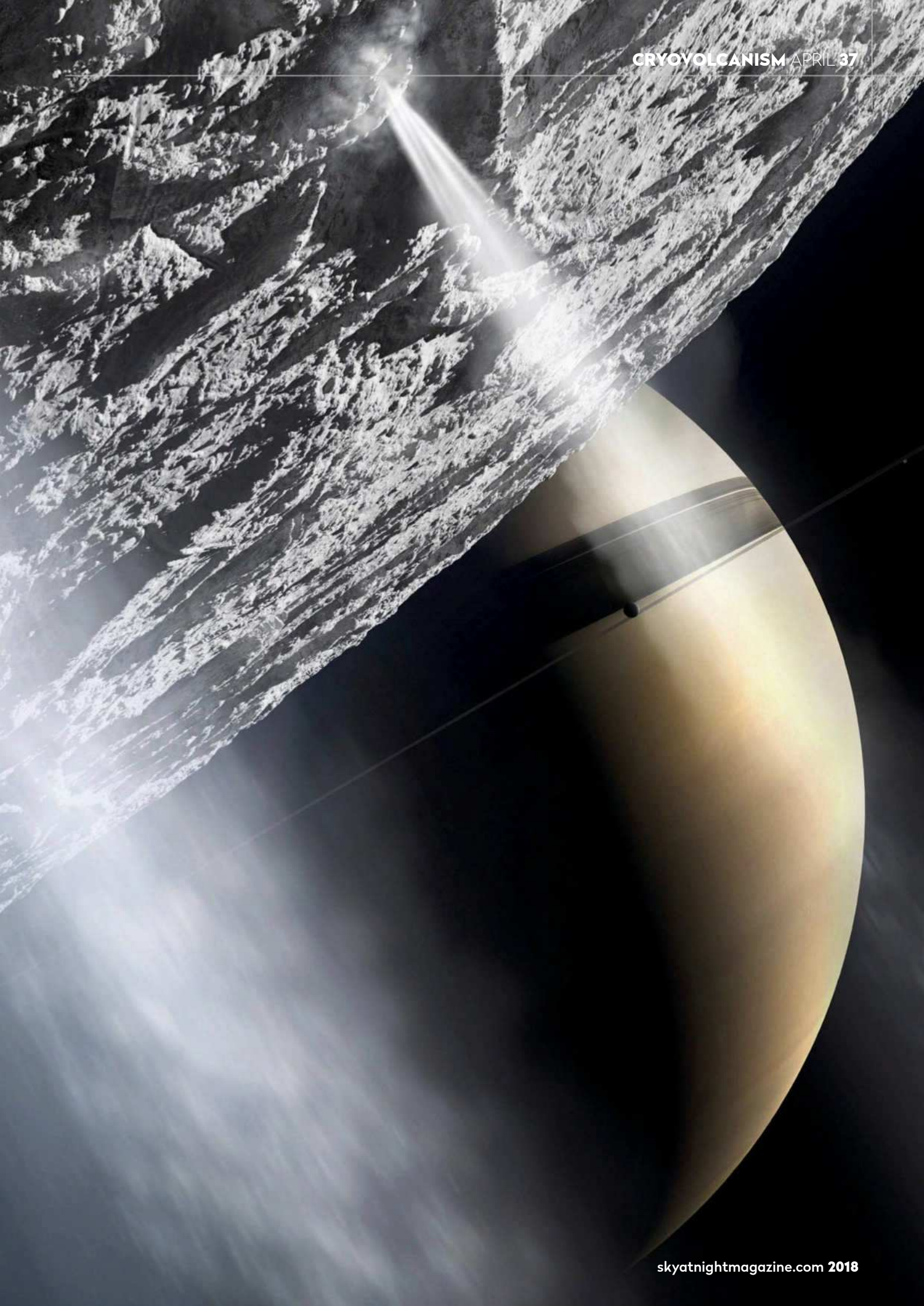
**ABOUT THE WRITER**
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor and holds a PhD in extragalactic astronomy

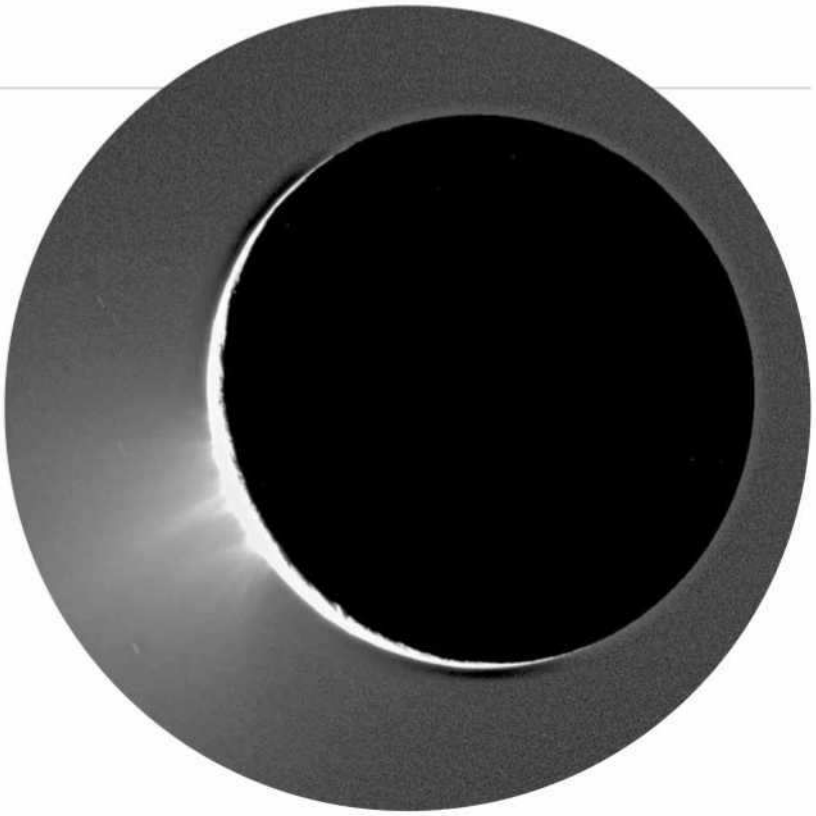
# When ice ERUPTS

Within our Solar System are moons with frozen volcanoes where ice flows like lava. **Elizabeth Pearson** investigates how cryovolcanism could provide the clues to finding inhabited environments

STOCKTREK IMAGES, INC. / ALAMY STOCK PHOTO

**An artist's impression of icy water jets erupting from Saturn's moon, Enceladus**





▲ Backlit by the Sun, icy jets are revealed erupting from beneath Enceladus's crust

The surface of Enceladus, Saturn's sixth-largest moon, is a cold and desolate wasteland where the temperature rarely rises above –200°C. But all is not as it first seems. Near the southern pole, the ground rumbles before a great volcanic burst erupts through the ice. But it is not lava that is escaping the moon's mantle – it's water.

Enceladus, like many of the icy moons of the Solar System's outer planets, plays host to the process of cryovolcanism – the seemingly contradictory term for volcanism that occurs many hundreds of degrees below freezing. While this frosty geology is also thought to take place on several dwarf planets, such as Ceres and Pluto, it is these ice worlds that have shown us what drives it.

The very idea of a 'frozen volcano' is so strange that it was never even considered a possibility until the Voyager missions in 1979. While flying past the moons of Jupiter and Saturn, the two spacecraft sent back images that looked very familiar to terrestrial volcanologists: they showed smooth lava plains, volcano-like mountains and craters. Scientists analysing the images asked themselves whether this was some bizarre, frigid facsimile of the volcanism we know so well in the inner Solar System.

"It looked volcanic, only we knew it wouldn't be molten rock because the density of these moons was too low to be rock," says Rosaly Lopes, a planetary geologist at NASA's Jet Propulsion Laboratory.

But the real smoking gun came in 1989, when Voyager 2 flew past Neptune's moon Triton and saw a plume of water rising 8km above the surface – an icy eruption gushing from a mantle of liquid water beneath the surface. Astronomers coined the term cryovolcanism to explain the new phenomenon where ice acted like rock and water was lava.

But the Voyagers zipped by their targets, giving only a tantalising glimpse of the worlds they passed. It wouldn't be until Cassini began orbiting Saturn in 2004 that we got our first real view of a cryovolcanically active world.

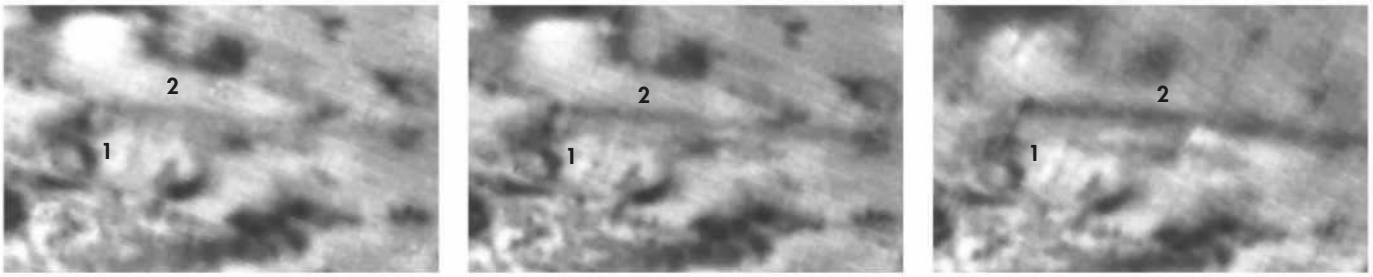
When Cassini arrived at Enceladus, it found evidence of a liquid layer hiding underneath the crust, which was acting as a mantle. The first direct evidence there was something actively happening in real time came in 2005, when the spacecraft saw a cloud of water above the surface. Later, images taken from Cassini's Imaging Science Subsystem confirmed the presence of jets coming from the moon's surface, and it was clear that liquid water was bubbling up from a layer under Enceladus's crust and dissipating out into space at 1,300 km per hour.

## The mystery of ice lava

A similar cloud was seen coming from the south pole of the Jovian moon Europa in 2012, showing that cryovolcanism can be found throughout our Solar System. However, as such cryovolcanic processes do not, and have never existed on Earth, researchers initially had no idea how the cryolavas of these distant worlds would act.

"The first work on cryolavas compared the viscosity and rheology – the properties of how material moves – of cryolavas to the way that lava flows here on Earth," says Lynnae Quick, a planetary volcanologist from the Smithsonian National Air and Space Museum.

These studies found that in many ways the two can behave similarly, despite having completely different temperatures and compositions. ▸




▲ Voyager 2 images from August 1989, showing an 8km-high ice volcano eruption on Neptune's moon Triton (1) and its trail drifting off to the right (2)

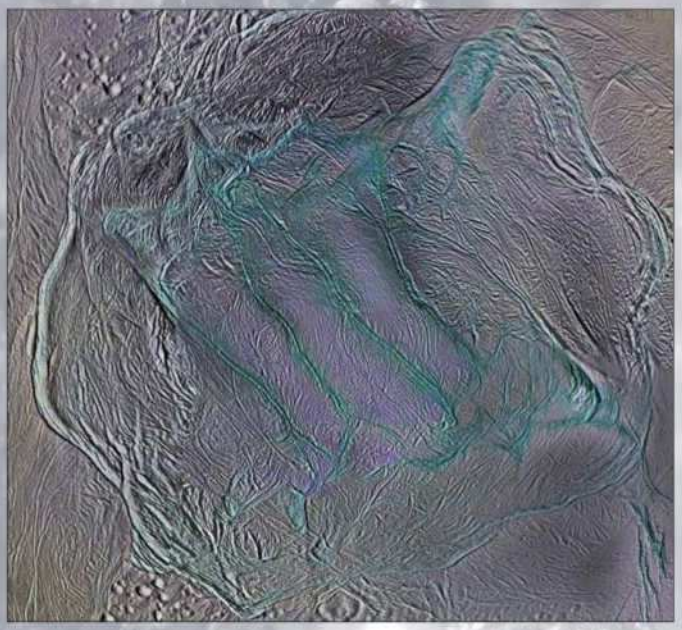
NASA/JPL/ASU, NASA/JPL, ISTOCK, NASA/ESA/L. ROTH/SWRI/UNIVERSITY OF COLOGNE, NASA/JPL-CALTECH/SSI/LUNAR AND PLANETARY INSTITUTE, PAUL SCHENK (LPI, HOUSTON), NASA/JPL/USGS, NASA/JPL-CALTECH/ASI/USGS/UNIVERSITY OF ARIZONA

# Spotting the signs

**There are many ways to identify potential cryovolcanic features**

## Water plumes

Water plumes have been spotted over Triton, Enceladus and Europa. These are enormous geysers of water that burst up through the planet's crust, sending plumes of water up to 100km into space.

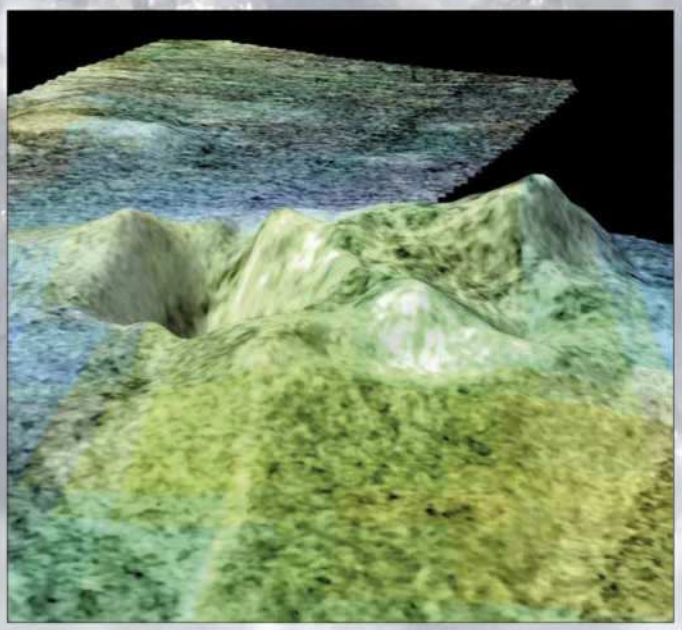


## Tiger stripes

On Enceladus, Cassini spotted four rifts known as 'tiger stripes', below where the plumes were spotted. These were 70°C hotter than the rest of the moon, suggesting that warm water was escaping from the interior.

## Young plains

Worlds with cryovolcanism often have highly reflective, smooth areas that are relatively free of craters, such as the Cipango Planum on Triton. This is because cryolava flows over craters made by meteors.



## Volcanoes

Several of the mountains on Saturn's moon Titan could in reality be volcanoes, such as the Sotra Facula region and its highest peak, Doom Mons. However, it is easy to mistake tectonic peaks for volcanic ones.

► The thick dome-forming lava on some moons resembles that of volcanoes like Mount St Helens

► "The average lava on Earth might erupt at 1,250°C, but on the icy moons it erupts at 0°C. That's considered freezing here on Earth, but in the outer Solar System it's very hot, because some of these bodies are at about –130°C," explains Quick. "On Earth we are thinking about molten rocks and in cryolavas we're talking about solutions of water and salt that may have some ice crystals in them – so they're more like a slush."

Although the icy satellites are mostly made from water, they do contain other dissolved substances such as nitrogen, methane and ammonia. These are only minor components of these moons, but they end up being hugely important to how the lavas of these planets act.

On Jupiter and Saturn, the lava is mostly composed of water with some ammonia and salts, but not many other water-soluble substances. This means that it has a low viscosity and is more likely to have effusive eruptions, where lava slowly oozes from the ground, creating floodplains similar to the Moon's mares.

Meanwhile, Uranus and Neptune's moons have lava with far more ammonia and methanol dissolved in the water, making it much thicker and more likely to form domes, like Mount St Helens on Earth. The dissolved gases are also volatile, meaning they tend towards explosive eruptions.

However, there are differences between hot and cold lavas – most notably the fact that, while solid rocks are denser than lava, and so sink, ice floats in water.

"The icy crust actually floats on top of the liquid mantle. So how can you make this liquid go through the crust, when the crust is denser?" asks Lopes. "There are various possibilities: the ammonia dissolved in the water could help; or maybe there is a squeezing process. People are still working on this."

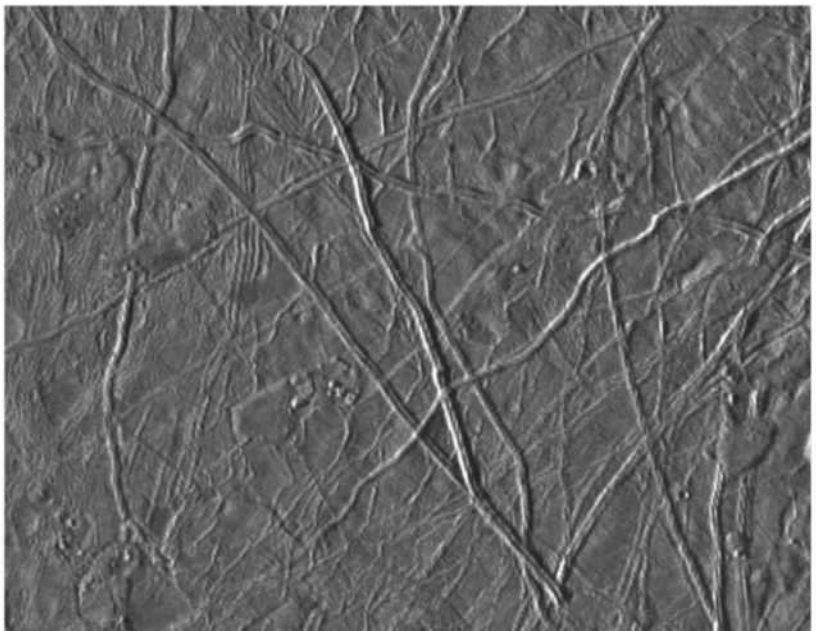
## The search for life

Although the mechanism that causes the cryolava to erupt is unknown, the fact that it does could provide an investigative opportunity for future missions to these icy worlds. The underwater oceans are thought to be the best places in the Solar System to hunt for extra-terrestrial life, but getting to them to have a look would require tunnelling through kilometres of ice. Instead, researchers could look at the material already brought to the surface via eruptions.

An early version of such a mission was carried out in 2015, when Cassini flew through one of the plumes over Enceladus. It found a high level of molecular hydrogen in the water, which could indicate the presence of hydrothermal vents on the ocean floor – potential hotspots for the formation of life. Cassini was built before we knew such plumes existed and it had no specialist sampling equipment. But the Europa Clipper, which is due to start making its way to the Jupiter system in the 2020s, will have instruments designed with the goal of flying through these plumes and sampling their chemistry.

"We really want to investigate the habitability of the moon with Europa Clipper," says Quick. "Once we have all the information telling us what environments on Europa might be most habitable, we can look for the best place to set down a future lander to actually get samples to analyse.

"I would like to put a lander by a cryolava flow and do a little scraping to find out the habitability of that area," she continues. "These lavas could be cycling organics between the surface and subsurface, in which case they could play a big role in creating habitable environments by bringing



▼ A 1997 image of possible ice lava flows on Jupiter's moon, Europa

WORLD HISTORY ARCHIVE/ALAMY STOCK PHOTO, NASA/JPL/ASU, NASA/JPL-CALTECH X 3, NASA/JPL-CALTECH/SETI INSTITUTE

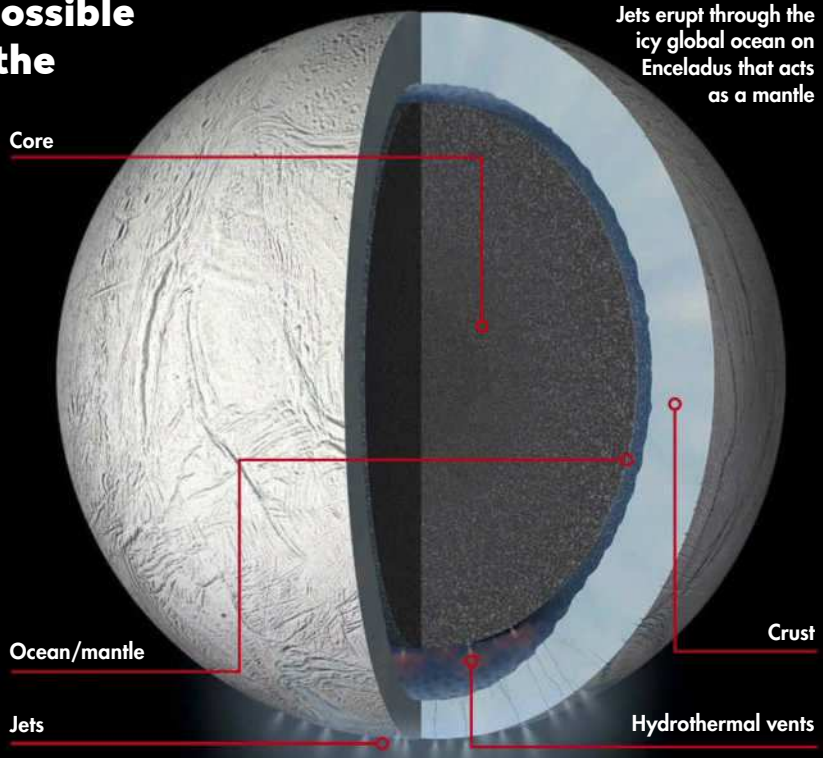
# Beneath the surface

## Cryovolcanism wouldn't be possible without a liquid layer under the crust acting as a mantle

The idea of a planet with cryovolcanic activity had never been considered before the Voyager missions, as it was thought the icy moons would be frozen solid. They are so far from the Sun that their surface temperatures are several hundred degrees below 0°C and all the residual heat – the thing that keeps our own planet's mantle from solidifying – should have dissipated. Without a mantle, there can be no volcanism.

What planetary scientists didn't account for, however, was the tidal tug-of-war between the various moons and their planet. This gravitational pull flexes the moons, keeping layers moving and preventing them from freezing completely. Instead of being frozen, then, these moons have liquid water oceans dozens of kilometres deep, sandwiched between the icy crust and a rocky core.

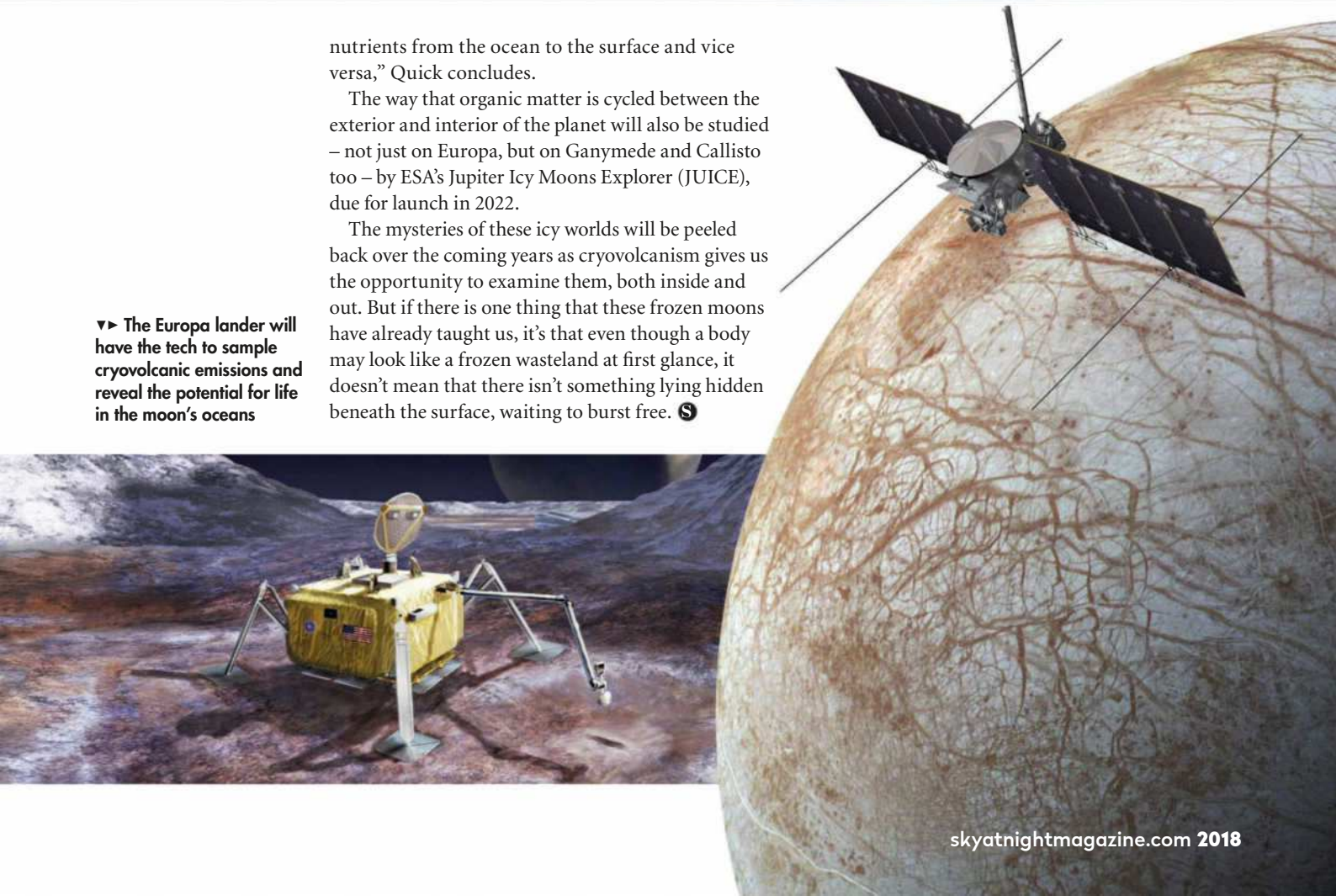
In most cases, it is possible to identify the presence of such an ice layer by looking at the moon's magnetic field. As the oceans contain some salts, they act as a conducting fluid, and their motion can effect or even create magnetic fields. These fields can then be monitored either directly from orbit by a spacecraft, or indirectly by watching their aurora.




nutrients from the ocean to the surface and vice versa," Quick concludes.

The way that organic matter is cycled between the exterior and interior of the planet will also be studied – not just on Europa, but on Ganymede and Callisto too – by ESA's Jupiter Icy Moons Explorer (JUICE), due for launch in 2022.

The mysteries of these icy worlds will be peeled back over the coming years as cryovolcanism gives us the opportunity to examine them, both inside and out. But if there is one thing that these frozen moons have already taught us, it's that even though a body may look like a frozen wasteland at first glance, it doesn't mean that there isn't something lying hidden beneath the surface, waiting to burst free.



▾▸ The Europa lander will have the tech to sample cryovolcanic emissions and reveal the potential for life in the moon's oceans

A BUYERS' GUIDE TO DARK-SKY LIGHTING

# Seize the NIGHT

The right kind of domestic lighting can make all the difference to stargazing. **Allan Howard** reveals how to mitigate the glare

Do your bit to combat obtrusive light by reducing the amount of domestic glare you're creating

IMAGE SOURCE/ALAMY STOCK PHOTO, ILLUSTRATION BY PAUL WOOTTON

**ABOUT THE WRITER**
Allan Howard is a past president and a current Fellow of the Institution of Lighting Professionals, with 33 years' experience in the lighting business

Artificial light can be a nuisance for many, particularly astronomers. Bright lights at night cause glare discomfort, disability and loss of darkness, all of which creates problems for anyone who wants to admire the splendour of a clear night sky. And 'obtrusive light' isn't just a nuisance for those at the eyepiece who'd like to be able to observe more stars; it can also have negative economic and ecological effects.

'Sky-glow' is the general, diffuse sheen visible in the direction of large cities, airports and industrial complexes. It occurs from both natural and artificial light sources and does not depend exclusively on lighting design, but also on atmospheric conditions. 'Glare' is the name we give to the uncomfortable brightness of a light source when viewed against a darker background.

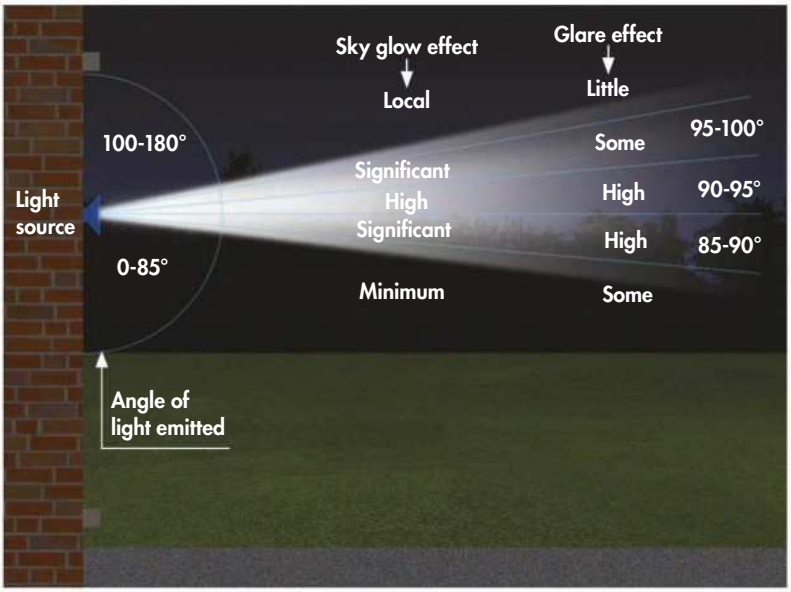
Light can be propagated into the atmosphere either directly upward or from incompletely shielded sources. It may also be reflected off the ground or other surfaces, partially scattering back towards observers and limiting the perceived darkness around them.

But lighting at night also has its uses, providing visibility and security around your home. Luckily, there are lights designed for domestic use that will keep your property safe and won't impact too much on your nightly observing.

Over the following pages, we reveal four types of lighting that can be used for security and safety around the home and garden, including some examples of astro-friendly units that will preserve the darkness. ▸

# Angling for darkness

**Modifying the position of a light source can diminish its polluting effects on the night sky**




▲ Higher mounting heights allow lower main beam angles, which helps reduce glare

A poorly positioned security light can lead to uncomfortable levels of glare

# SECURITY LIGHTS

Domestic security lights should provide the minimum level of illumination to light a single property, not half the street. Because of the price and ease of installation, many people install tungsten halogen floodlights, which can provide satisfactory security lighting. It is rarely necessary to use a lamp greater than 2,000 lumens (150W). These lights can be fitted with detectors to sense the movement of intruders, but often the systems require the detector and the floodlight to be aimed in the same direction.

## SUGGESTED MODELS

**Blooma Pietas external security floodlight**
Manufacturer: B&Q
Price range: £30-£40

**Die-cast aluminium LED wall luminaire**
Manufacturer: Lutec
Price range: £70-£110

# SOS: Save Our Skies

**Concerned about light pollution? Dark-skies campaigner Steve Owens says communities can make a difference**

There is always value in getting people stargazing. The more engagement you have with your community, the more you can make them recognise the value of dark skies and the more likely they are to approve planning policies that protect those skies.

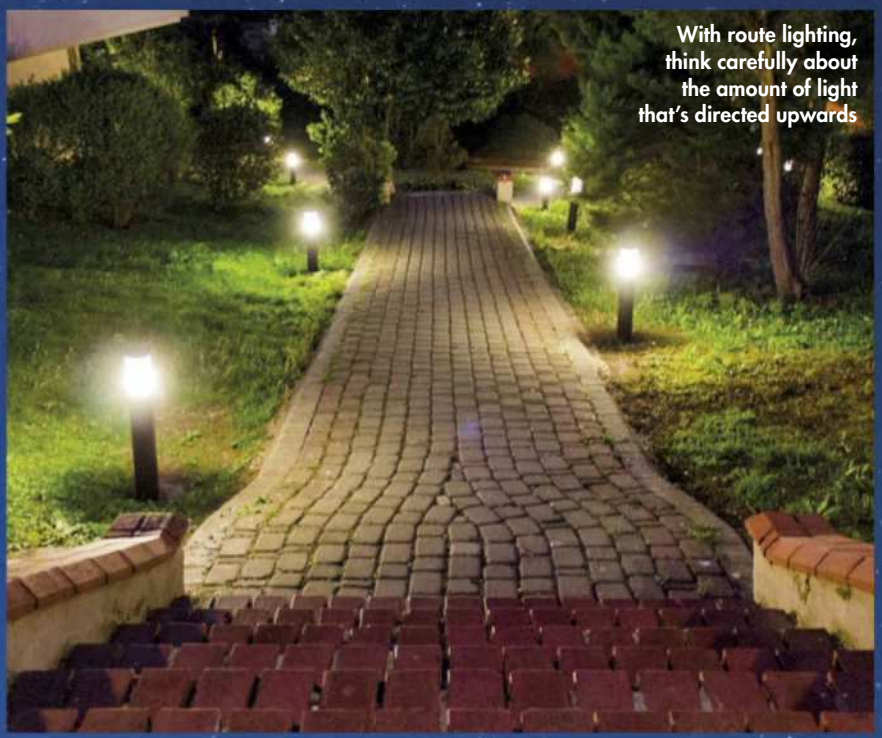
The Isle of Coll in the Inner Hebrides is an International Dark Sky Association (IDA) Dark Sky Community thanks to the work of the Coll Dark Skies Group. County Kerry in Ireland now has an IDA International Dark Sky Reserve as the result of a campaign led by the local astronomy society. In the case of Galloway Forest Dark Sky Park, attracting tourism was a huge drive in arguing the case.

On a smaller scale, astronomy societies can help designate Dark Sky Discovery (DSD) sites by working with their community. A word of warning, though: I've found that when it's just astronomers complaining about their hobby being spoiled, it's a hard sell; what has worked is attending your local council meetings or talking with friends and neighbours and letting them know the environmental reasons why they wouldn't want bad outdoor lighting in their area. It's about finding the right route: a Dark Sky designation can create publicity and generate local interest. If there's a park in your community that you've always used for stargazing, but the council are planning on building houses near it, run public events there and get the community on board. This creates more of a narrative about why these sites are necessary. Make the point that it's important to people, and it won't cost the council more money to install good lighting instead of bad lighting; it's just a case of thinking about it in the first place.

**In 2009, Galloway Forest Park became the UK's first ever Dark Sky Park**

**Steve Owens is CEO of The Crawick Multiverse in Dumfries and Galloway, and a Dark Skies campaigner who sits on the DSD steering group.**

# ROUTE LIGHTING



**With route lighting, think carefully about the amount of light that's directed upwards**

**Low-level bollard lighting can be useful for illuminating a garden path or footway to make walking to and from your house at night easier and safer. However, if you're wary of flooding your observing areas with light, it is important to consider the light distribution from these units and ensure that it's directed downwards. This will avoid any glare towards the observer. Owing to their short height and the local distribution of their light, you may need to space these units fairly close together.**

## SUGGESTED MODELS

**Rusty Slot 50 outdoor post light**
Supplier: SLV
Price range: £130-£270

**Lucide combo outdoor LED post light**
Supplier: Lucide
Price range: £60-£85

ISTOCK X 3, ARCH WHITE/ALAMY STOCK PHOTO

# Easy on the eye

**How does light affect the eye of the observer, and what can be done to maintain maximum night vision?**

When observing the night sky, the human eye becomes nearly or completely dark-adapted, or 'scotopic'. The scotopic eye is much more sensitive to blue and green light and much less sensitive to yellow and red light than the daytime-adapted, or 'photopic', eye.

Different light sources have different levels of apparent brightness to the dark-adapted eye. White light sources such as metal halide, fluorescent or white LED can produce up to three times the visual sky glow brightness of a high-pressure sodium lamp.

Astronomers tend to use a red light source to view star charts, books and notepads in the dark, as this helps to protect night vision adaption. Information printed in white text on black paper also helps maintain dark-adapted vision, because the light reflected back into the eye is considerably reduced.

What's black and white and red all over? An astronomer's notepad at night-time

# PORCH LIGHTING

**Another option is a bulkhead or porch light fitted with a low-power 600-900 lumen (9-11W) compact fluorescent lamp. These units can be left on all night, providing security for only a few pounds of electricity per year. This light is also kinder to the environment, providing a gentle wash of light with reduced glare. Fluorescent lamps cast fewer shadows, reducing hiding places for criminals, and can be fitted with a movement detector if required. These units are generally mounted lower and are therefore less likely to elicit complaints from neighbours.**


Porch lighting can provide a gentle wash of light

# SUGGESTED MODELS

**LED Solar Flush wall light with PIR sensor**
Manufacturer: Selected by suppliers
Price range: £14-£16

**Ghost LED solar wall light with PIR sensor**
Manufacturer: Lutec
Price range: £50-£75

ISTOCK X 3

When lighting a wide area, avoid the temptation to install units too close together

# GARDEN LIGHTING

When installing lighting to illuminate a large outside area, the same principles apply as with the positioning of domestic security lighting. What you need to take into consideration is the height at which the lights will be mounted and the amount of distance between each of the lighting units. For areas such as the garden, your driveway or other large external spaces, spacing the lighting units at around 2.5 times the height of the mounting should provide you with the correct lighting performance.

## SUGGESTED MODELS

**Kaskara area projector**
Manufacturer: DW Windsor
Price range: £300+

**Neos LED**
Manufacturer: Schréder
Price range: price on application

## Where to buy

Shopping around online is a good way to compare prices for the kind of lighting you want to buy. The following websites may be a good starting point:

| | |
|---|---|
| **Lighting Direct:** | **www.lighting-direct.co.uk** |
| **TLC Electrical supplies:** | **www.tlc-direct.co.uk** |
| **TradePoint:** | **www.trade-point.co.uk** |
| **Lyco:** | **www.lyco.co.uk** |

## Earth Hour

On 24 March 2018 at 8.30pm (local time), join 172 countries and territories around the globe by turning off your lights for an hour or more to highlight the importance of dark-sky preservation and reducing obtrusive light.

# Join an evening of night sky viewing with The Sky at Night's **Pete Lawrence**

**Join expert astronomer, award-winning astrophotographer and TV presenter Pete Lawrence for a unique astronomy and astrophotography experience. This break takes us to one of two stunning observatories where we'll enjoy fascinating astronomy lectures, workshops, practical activities and the unique opportunity to do some night sky viewing with expert commentary and guidance from Pete Lawrence. Don't miss out on this special chance to experience spectacular hands-on science and discovery among domes and telescopes in a world famous astronomical observatory.**

## Upcoming Dates

**Herstmonceux Observatory, East Sussex**
**2 days, Sat 28 Apr 18** - only **£180pp** **Last few places**

**Kielder Observatory, Northumberland**
**2 days, Sun 24 Jun 18** - only **£225pp**

## Price Includes

- ✓ 1 night's accommodation
- ✓ Dinner & full English breakfast
- ✓ Return coach transfers
- ✓ Entrance to the observatory
- ✓ Lectures, workshops and night sky viewing with Pete Lawrence

Photograph - courtesy of Will Gater

## ECLIPSE 2019

3 incredible itineraries to choose from:

*Peru & Chile Discovery*
**12 days, Mon 24 Jun 19** - from **£6,450pp**

*Chilean Explorer*
**11 days, Mon 24 Jun 19** - from **£5,950pp**

*Chile in a Nutshell*
**8 days, Sat 29 Jun 19** - from **£4,950pp**

Joined by our expert guides **Pete Lawrence** & **Will Gater**

**All itineraries include flights, accommodation, transfers and much more ...**

**Order your copy of our 2018/19 Astronomy & Astrophotography brochure today!**

For more information or to book, please call:

# 0330 013 0071

or visit **omegabreaks.com/skyatnight**

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ABTA

*Tours offered subject to Omega Holidays terms and conditions. All tours offered subject to availability. Errors and omissions excepted. Prices shown are per person, based on two people sharing a dbl/twin room. Single supplements apply. Calls to 033 numbers are free within inclusive minutes packages otherwise standard rates apply. Warning: never look at the Sun with just your eyes or through any optical instrument without using appropriate and certified protective filters.*

# The Sky Guide • April

PETE LAWRENCE

**There's a great opportunity to see the brilliant planet Venus and a lovely crescent Moon near the spectacular open clusters of Taurus mid-month**

## ABOUT THE WRITERS

Pete Lawrence is an astronomer and astro imager, and presents *The Sky at Night* monthly on BBC Four.

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 60.

## RED LIGHT FRIENDLY

To preserve your night vision, The Sky Guide can be read using a red light under dark skies.

## DON'T MISS...

- Mars lies close to Saturn on top of the Teapot asterism.
- The April Lyrid meteor shower reaches its peak.
- Jupiter appears to gain a brand new moon.


# APRIL **HIGHLIGHTS**

Your guide to the night sky this month

## SUNDAY 1

There is a very brief opportunity to grab a double shadow transit of Io's and Ganymede's umbras at 02:10 BST (01:10 UT). If you miss both shadows in transit together, the remaining transit of Ganymede's shadow across the northern part of Jupiter's disc should look amazing.

## MONDAY ▶ 2

Mars and Saturn appear just 1.3° apart in the early hours. At 03:50 BST (02:50 UT) Mars lies 22 arcminutes north of the mag. +6.5 globular cluster M22.

## THURSDAY 5

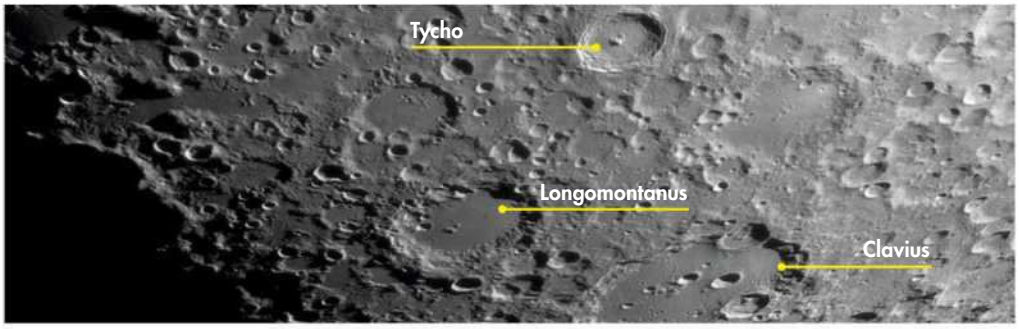
Today sees the beginning of activity from the Gamma Virginid meteor shower. The shower has a low maximum ZHR of just five meteors per hour during its peak period on 14 and 15 April. Activity continues until 21 April.

## SATURDAY 7

There is a lovely grouping of the Moon, Mars and Saturn low above the southeast horizon before dawn this morning. A similar arrangement can be seen on the morning of 8 April too, with the Moon now to the east of the planets. See page 52 for more details.

## MONDAY ▶ 9

This morning and tomorrow morning, look out for our Moonwatch crater, Longomontanus (see page 58). The lunar night is approaching this 146km-diameter feature, generating long, dramatic shadows as the evening terminator moves ever nearer.




## SATURDAY ▶ 14

The lack of Moon interference around midnight makes this a perfect time to go galaxy hopping in the Realm of Galaxies. This is a galaxy-rich part of the sky located within and to the north of the Bowl of Virgo.

## TUESDAY 17

This evening's 3%-lit waxing crescent Moon lies 6° south of mag. –3.8 Venus, a stunning sight, visible low in the west-northwest from approximately 30 minutes after sunset.

PETE LAWRENCE X 7

## ◀ WEDNESDAY 25

Jupiter reaches opposition two weeks from today on 9 May. Grab every clear night opportunity to view this amazing planet over the weeks surrounding opposition.

## THURSDAY 26

Jupiter appears to gain an extra 'moon' this evening in the shape of mag. +9.1 HIP 74235. The star appears 1.25 arcminutes from the planet as the sky darkens. See page 53 for further information.

## SUNDAY 29

Mercury reaches greatest western elongation, visible in the morning sky. Although this is a favourable elongation of 27°, Mercury isn't well positioned, only rising in the east a few minutes before the Sun.

## TUESDAY ▶ 3

This morning and tomorrow morning a bright waning gibbous Moon sits close to mag. –2.2 Jupiter. View the pair due south at around 03:45 BST (02:45 UT).

## SUNDAY 8

As the dawn sky is getting brighter, take a look at Jupiter around 06:15 BST (05:15 UT) and you should be able to see Ganymede's giant shadow crossing its disc. See how long you can keep it in view as the Sun rises.

## ◀ THURSDAY 12

With the Moon out of the way, the fabulous sight of M13, the Great Globular in Hercules, can be viewed at its best. This brilliant object is easy to find, located one-third of the way down the western side of the distinctive Keystone asterism in Hercules.

## ◀ SATURDAY 21

The Lyrid meteor shower peak is approaching. Predicted to occur between 11:00 and 22:00 BST (10:00 and 21:00 UT) on 22 April, tonight and tomorrow night are the best time to view. The Lyrids have a maximum ZHR of 18 meteors per hour.

## SUNDAY 22

This evening presents a good opportunity to catch the formation of the lighting effect known as the Lunar X, along with its alphabetical associate the Lunar V. The effect should be at its peak around 21:40 BST (20:40 UT).

## TUESDAY 24

If you have a flat west-northwest horizon, locate brilliant Venus shortly after sunset and stay with it as the sky darkens. The planet lies 3.8° south of the Pleiades open cluster, visible as the sky darkens. From the UK, the Pleiades appear above and right of Venus.

## MONDAY 30

Jupiter occults the mag. +10.8 star TYC 6169-372-1 between 01:24 and 02:21 BST (00:24 and 01:21 UT). This will be a difficult event to see. Later in the evening, Jupiter can be seen 3.5° southwest of the full Moon.

## FAMILY STARGAZING – 17 APR

**Venus is now prominent in the evening sky and makes a great target to impress young minds. This is the brightest of all the planets, its intense brilliance coming from its dense, reflective atmosphere. See how soon after sunset you can spot it, low in the west to west-northwest. Make a game of who can see it first in the evening twilight, but make sure the Sun has set before you try! If it's clear on 17 April, Venus and a 3%-lit crescent Moon also provide a fantastic sight. www.bbc.co.uk/cbeebies/shows/stargazing**

## NEED TO KNOW

The terms and symbols used in *The Sky Guide*

**UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)**
**Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.**

**RA (RIGHT ASCENSION) AND DEC. (DECLINATION)**
**These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.**

**FAMILY FRIENDLY**
Objects marked with this icon are perfect for showing to children

**NAKED EYE**
Allow 20 minutes for your eyes to become dark-adapted

**PHOTO OPPORTUNITY**
Use a CCD, planetary camera or standard DSLR

**BINOCULARS**
10x50 recommended

**SMALL/ MEDIUM SCOPE**
Reflector/SCT under 6 inches, refractor under 4 inches

**LARGE SCOPE**
Reflector/SCT over 6 inches, refractor over 4 inches


## GETTING STARTED IN ASTRONOMY

**If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.**

# THE BIG **THREE**

The three top sights to observe or image this month

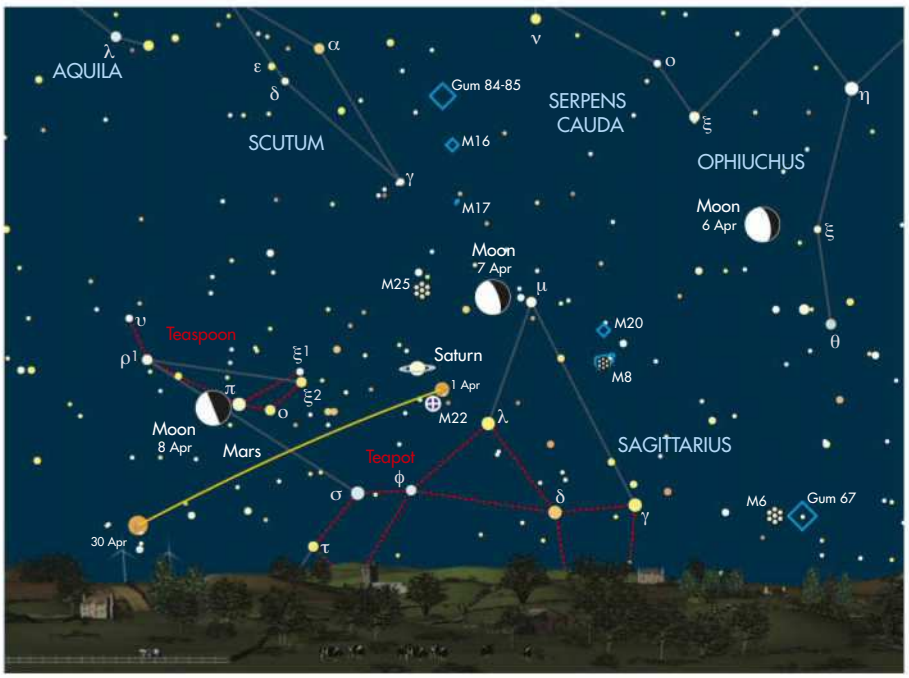
## DON'T **MISS**

## Mars, Saturn and the Teapot

**WHEN:** Throughout April

Mars and Saturn are visible in the morning sky with both planets located in Sagittarius at the start of the month, just north of the Teapot asterism and close to Kaus Borealis (Lambda (λ) Sagittarii), the star marking the top of the teapot's lid. Viewing them is a bit of a balancing act throughout the month as the nights are now rapidly decreasing in length.

At 04:30 BST (03:30 UT) during the start of April, both planets appear roughly 6° above the southeast horizon and, given a clear view in this direction, should be easy to spot. Mars will be at mag. +0.3 and appear distinctly orange or salmon-pink in colour. Saturn will be dimmer at mag. +0.9, yellow-white in colour. On the morning of 1 April, they appear 1.5° apart.




▲ **With clear viewing conditions, both Mars and Saturn should be easy to spot roughly 6° above the southeast horizon, with some good opportunities for interesting astrophotography**

This distance decreases on the morning of 2 April as Mars drifts further to the east.

On the morning of 2 April, Mars will be 22 arcminutes north of the mag. +6.5 globular cluster M22. This should be an interesting challenge if you're into astrophotography. On the mornings of 2 and 3 April the apparent separation between both planets will be just 1.3°, increasing to 1.5° again on the morning of 4 April.

The arrangement at the start of the month provides a good opportunity for wide-field astrophotography as this is a rich and interesting area due to its proximity to the bright core of the Milky Way. A low altitude in early April doesn't do the Milky Way any favours, but objects such as the bright open cluster M25, 3.5° north of Saturn, will really add to the view.

On the morning of 7 and 8 April the Moon joins the party. On 7 April its 60% waning gibbous disc can be seen forming an approximate line with Mars and Saturn, the Moon to the west, Mars to the east and Saturn slightly offset towards Mars in between. On the morning of 8 April, the last quarter Moon will have overtaken Mars to become the most easterly of the three.

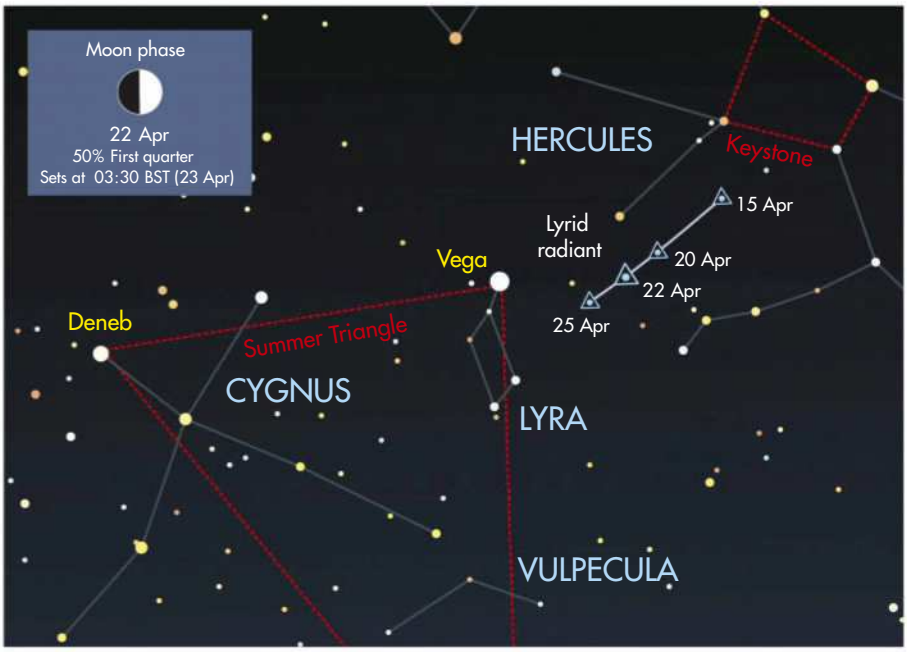
From 11–25 April, Mars will be located south of the Teaspoon asterism, again moving east. By the end of the month, both planets will appear separated by 14° and are best viewed at 03:00 BST (02:00 UT) just before the onset of astronomical twilight. Saturn will have brightened to mag. +0.7 on 30 April, completely outshone by the now rather splendid sight of orange Mars at mag. –0.4.

PETE LAWRENCE X 4

▲ **By 2 April, a salmon-pink Mars and yellow-white Saturn will appear just 1.3° apart**

# April Lyrids

**WHEN:** Nights of 21/22 and 22/23 April through to 02:30 UT




▲ Lyrid meteors appear to emanate from a radiant located west of Vega

The start of the annual meteor calendar is marked by the Quadrantid shower which reaches its peak at the start of January. After that, apart from a few very minor showers, there's little significant activity to be had until the April Lyrids. This shower reaches its peak on the night of 22 April. Although the Lyrids' usual Zenithal Hourly Rate (ZHR) isn't that spectacular, typically around 18 meteors per hour, the location from which the meteors appear to emanate from in the sky – known as the shower radiant – does reach a high altitude. This year, the Moon is out of the way on 22 April, which means that as long as the weather holds, viewing conditions will be very favourable indeed.

The shower is active 14–30 April, with the radiant located to the west of the bright star Vega (Alpha (α) Lyrae) at the time of maximum activity. The parent body for the Lyrid shower is comet C/1861 G1 Thatcher. When debris strewn around the comet's orbit encounters Earth, it vaporises in our planet's atmosphere, creating the streaks known as meteor trails.

The debris stream is not uniform and at approximately 60-year intervals we see an enhancement of Lyrid activity. In 1982 the peak rate went up to an impressive 90 meteors per hour, similar to activity seen in 1922. Impressive though these rates are, they pale in comparison to the 700 meteors per hour that were seen in 1803.

This year's peak is expected to occur at 19:00 BST (18:00 UT) on 22 April, with rates typically above half peak values for 32 hours centred on this time. This means the best views are likely to be had on the nights of 21/22 and 22/23 April, viewing all night through to around 03:30 BST (02:30 UT).

# Jupiter's extra 'moon'

**WHEN:** Nights of 25/26 and 26/27 April

**The term planet comes from the Greek 'planetes' or 'wandering stars', so given because these bodies appear to move against the 'fixed' stars. It's not unreasonable to think that, as they move, they can pass close to background stars, but this is less common than you might think. Jupiter's four largest and brightest moons, Io, Europa, Ganymede and Callisto, orbit close to the planet's equatorial plane. If Jupiter does wander near to a star, it's usually obvious that the star is an interloper because it doesn't line up with Jupiter's equatorial plane.**

**On the night of 25/26 April, a ninth-magnitude star, HIP 74235 does line up to the left of the planet, in line with Jupiter's equatorial plane. The other Galileans will be notably brighter, so there shouldn't be any real confusion as to which is which. On the following night, the same star can be seen much closer to Jupiter's disc, just to the north of Callisto, with Io below it. Just after rising, this 'imposter moon' lies 1.5 arcminutes from the centre of Jupiter.**

**If you're up for a challenge, on 30 April, Jupiter will occult a mag. +10.8 star, TYC 6169-372-1 between 01:24 and 02:21 BST (00:24 and 01:21 UT). Jupiter's brightness will make this really hard to observe.**

**Jupiter gained an extra 'moon' on 12 April 2016 in the form of HIP 54057, third from the left**

# THE NORTHERN HEMISPHERE IN APRIL

## KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

**STAR BRIGHTNESS:**

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW
- MILKY WAY

## WHEN TO USE THIS CHART

**1 APR AT 01:00 BST**
**15 APR AT 00:00 BST**
**31 APR AT 23:00 BST**

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

## HOW TO USE THIS CHART


1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

## SUNRISE/SUNSET IN APRIL*

| DATE | SUNRISE | SUNSET |
|---|---|---|
| 1 Apr 2018 | 06:44 BST | 19:45 BST |
| 11 Apr 2018 | 06:20 BST | 20:03 BST |
| 21 Apr 2018 | 05:57 BST | 20:22 BST |
| 01 May 2018 | 05:36 BST | 20:40 BST |

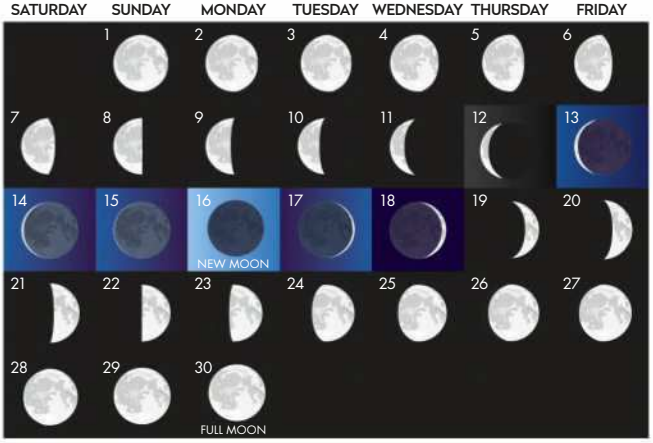
## MOONRISE IN APRIL*

**MOONRISE TIMES**

| | |
|---|---|
| 01 Apr 2018, 20:57 BST | 17 Apr 2018, 07:17 BST |
| 05 Apr 2018, 00:27 BST | 21 Apr 2018, 10:00 BST |
| 09 Apr 2018, 03:54 BST | 25 Apr 2018, 14:51 BST |
| 13 Apr 2018, 05:46 BST | 29 Apr 2018, 19:52 BST |

*Times correct for the centre of the UK

## LUNAR PHASES IN APRIL



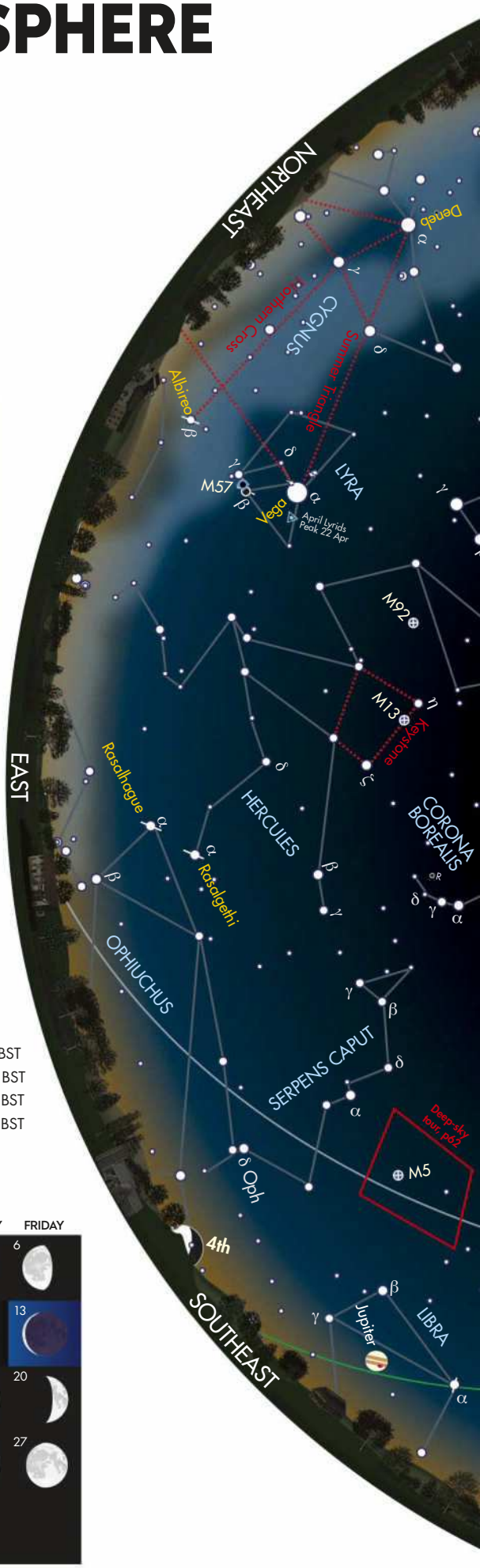
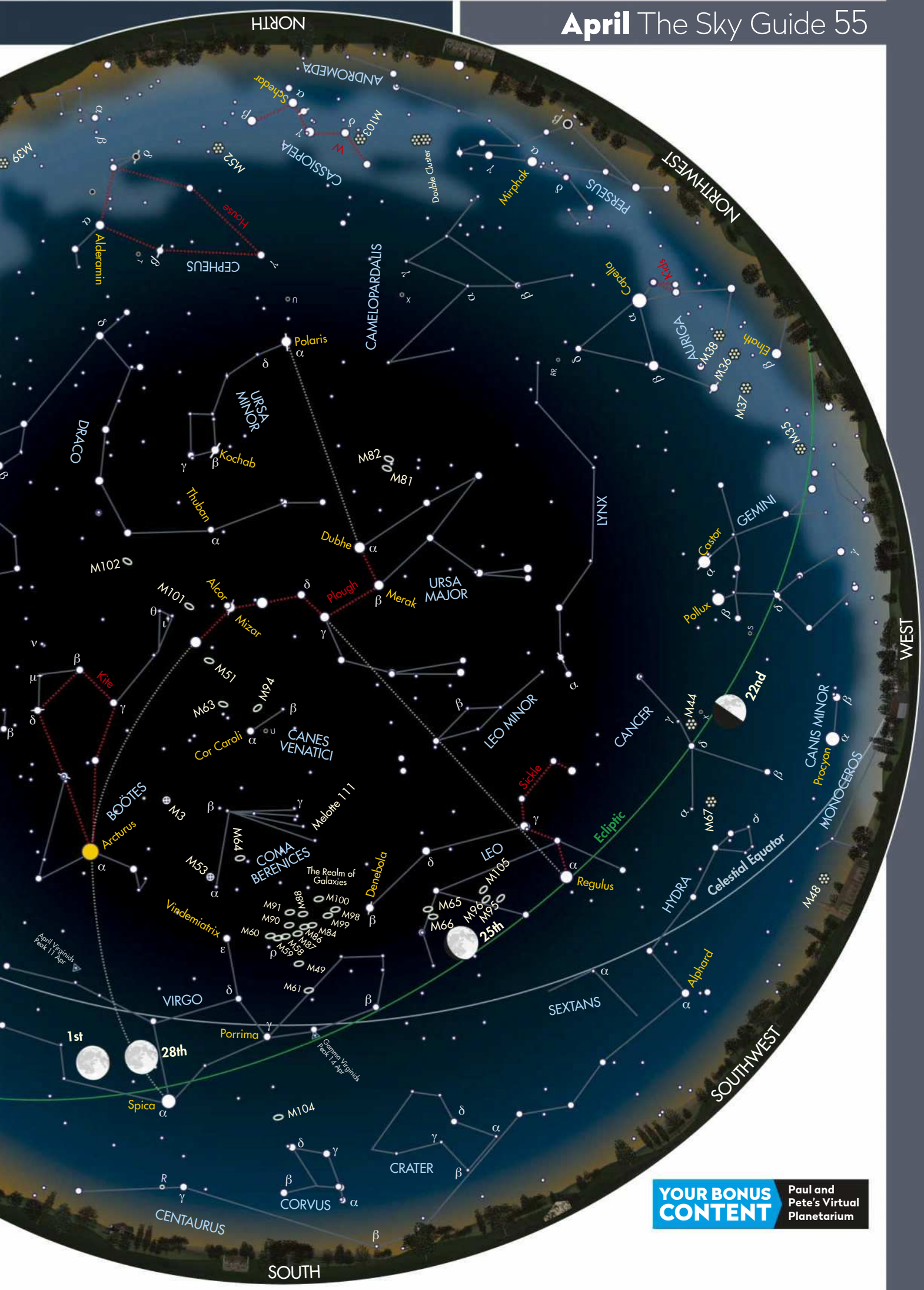




CHART: PETE LAWRENCE



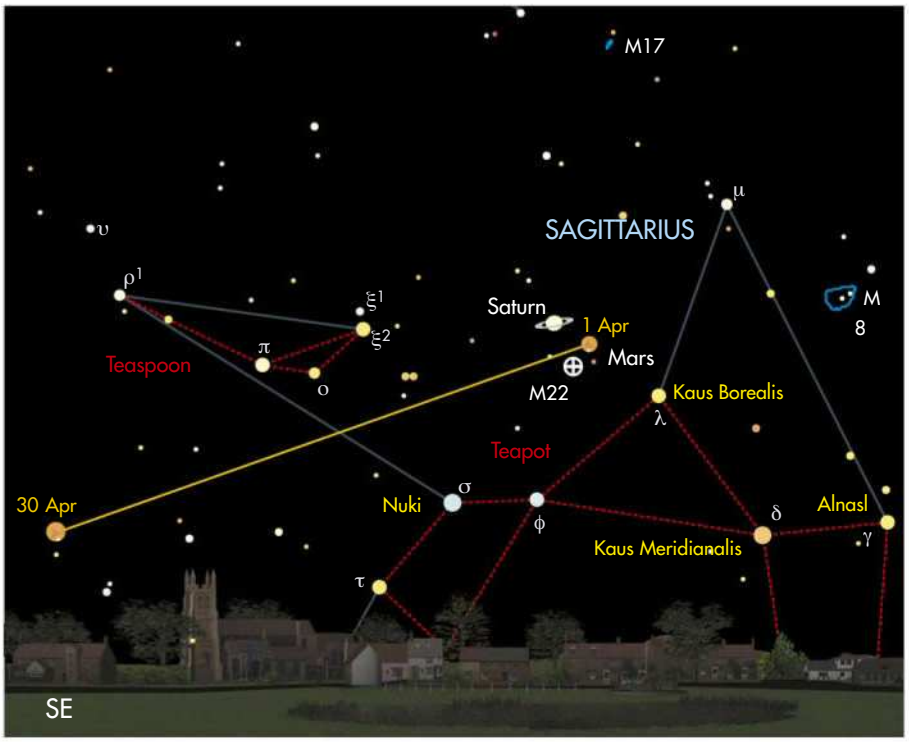

**YOUR BONUS CONTENT** Paul and Pete's Virtual Planetarium

# THE **PLANETS**

## PICK OF THE MONTH

### MARS

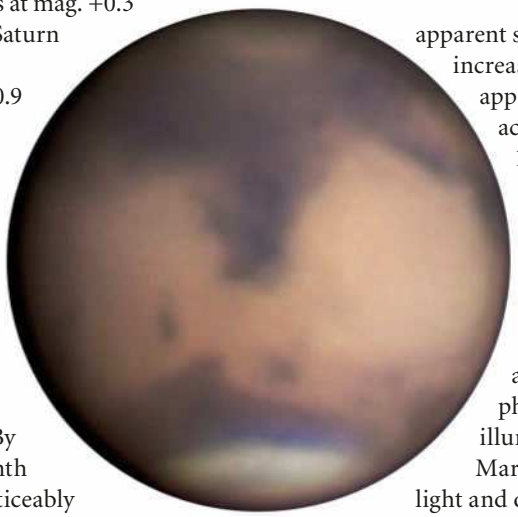
**BEST TIME TO SEE:** 2 April, from 05:00 BST (04:00 UT)
**ALTITUDE:** 9° (low)
**LOCATION:** Sagittarius
**DIRECTION:** South-southeast
**FEATURES:** Surface markings, weather, polar caps
**EQUIPMENT:** 75mm or larger scope




▲ **Increased apparent size and brightness in April make it a good time to spot Mars's features**

Mars has a close encounter with Saturn this month, both planets appearing separated by 1.3° on 2 April. At this time both planets are close to the Teapot asterism in Sagittarius, not too far from Kaus Borealis (Lambda (λ) Sagittarii), the star which marks the top of the teapot's lid. Mars is at mag. +0.3 on this date, with Saturn appearing slightly dimmer at mag. +0.9 and of course, there's a significant colour difference between orange Mars and yellow-white Saturn.

A waning gibbous Moon joins the separating planets on 7 and 8 April. By the end of the month Mars increases noticeably in brightness from mag. +0.3 on 1 April to mag. –0.4 by 30 April. Through a telescope its apparent size is also on the increase. On 1 April it appears 8 arcseconds across, growing to 10 arcseconds across by the end of the month. Throughout this period, a telescope reveals the planet to have a waxing gibbous phase, 88% illuminated.



PETE LAWRENCE X 3

▲ **Mars with Syrtis Major and the north polar cap on view**

Mars is a planet of light and dark. The lighter regions include the bright polar caps and desert areas, while the darker regions mainly consist of exposed rock. It's the southern pole of Mars which is tilted towards Earth at present.

The features do change in subtle ways as material shifts around the planet, but for the most part the general form is fairly consistent. The most famous dark feature is the V-shaped Syrtis Major. There is a good opportunity to catch this dark marking on an admittedly low altitude, early morning Mars from 20 April.

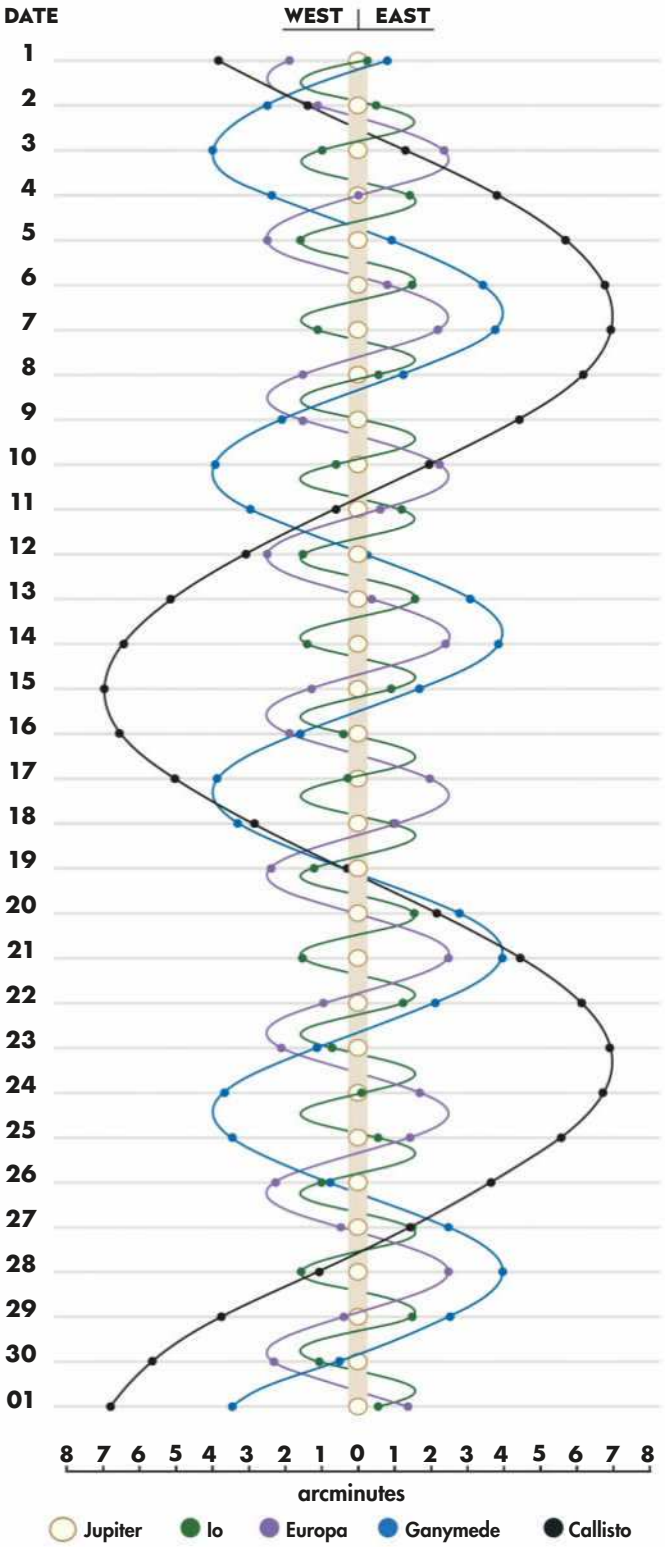
Observing Mars can be a challenge and it's essential to allow your eye to get used to the view. The planet's low altitude for those viewing it from the UK won't help, but with persistence and a bit of luck with the seeing, the views you can get of this amazing world are definitely worth putting in the effort for.

## THE PLANETS IN APRIL

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope

# JUPITER'S MOONS APRIL

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.




## Mercury

Mercury isn't well placed this month, rising almost at the same time as the Sun.

## Venus

**Best time to see:** 30 April, 21:00 BST (20:00 UT)
**Altitude:** 17°
**Location:** Taurus
**Direction:** West-northwest

Venus is now a dazzling sight over towards the west after sunset. The planet remains at mag. –3.8 all month as it gradually increases its apparent separation from the Sun. Venus is optimally positioned throughout April, setting nearly 3 hours after sunset by the end of the month – a telescope will show it to have an 11 arcsecond, 88% lit disc. On 22–26 April, it can be seen passing to the south of the lovely Pleiades open cluster, M45, in Taurus. On 24 April, Venus sits 3.5° to the south of the cluster, presenting a wonderful opportunity for photography. By the end of the month, Venus appears to pass a similar distance to the north of the V-shaped Hyades open cluster, also in Taurus.

## Jupiter

**Best time to see:** 30 April, 01:50 BST (00:50 UT)
**Altitude:** 20°
**Location:** Libra
**Direction:** South

Jupiter is now a major feature of the night sky. It's technically a morning object approaching opposition but rises in darkness at 23:30 BST (22:30 UT). It manages to climb to its highest position due south around 04:00 BST (03:00 UT) at the start of the month and, although nothing like as high as it has been in recent years, this is the best time to try to view the planet. Jupiter's atmosphere can present a wealth of detail through even modest amateur telescopes. Its four biggest and brightest moons are also fascinating to watch. In particular, look out for the shadow of Ganymede transiting Jupiter's disc on the morning of 8 April (see Calendar, page 51). On 1 April, Jupiter shines at mag. –2.2 and through a telescope presents a substantial 42 arcsecond disc. A bright waxing gibbous Moon appears to sit near to the planet on the mornings of 3 and 4 April. By the end of the month, Jupiter will have drifted slightly to the west through Libra, but remains within the main outline of the constellation. On 30 April, Jupiter's brightness will have increased to mag. –2.3 and its apparent diameter will sit at 44 arcseconds.

## Saturn

**Best time to see:** 30 April, 03:50 BST (02:50 UT)
**Altitude:** 12°
**Location:** Sagittarius
**Direction:** South-southeast

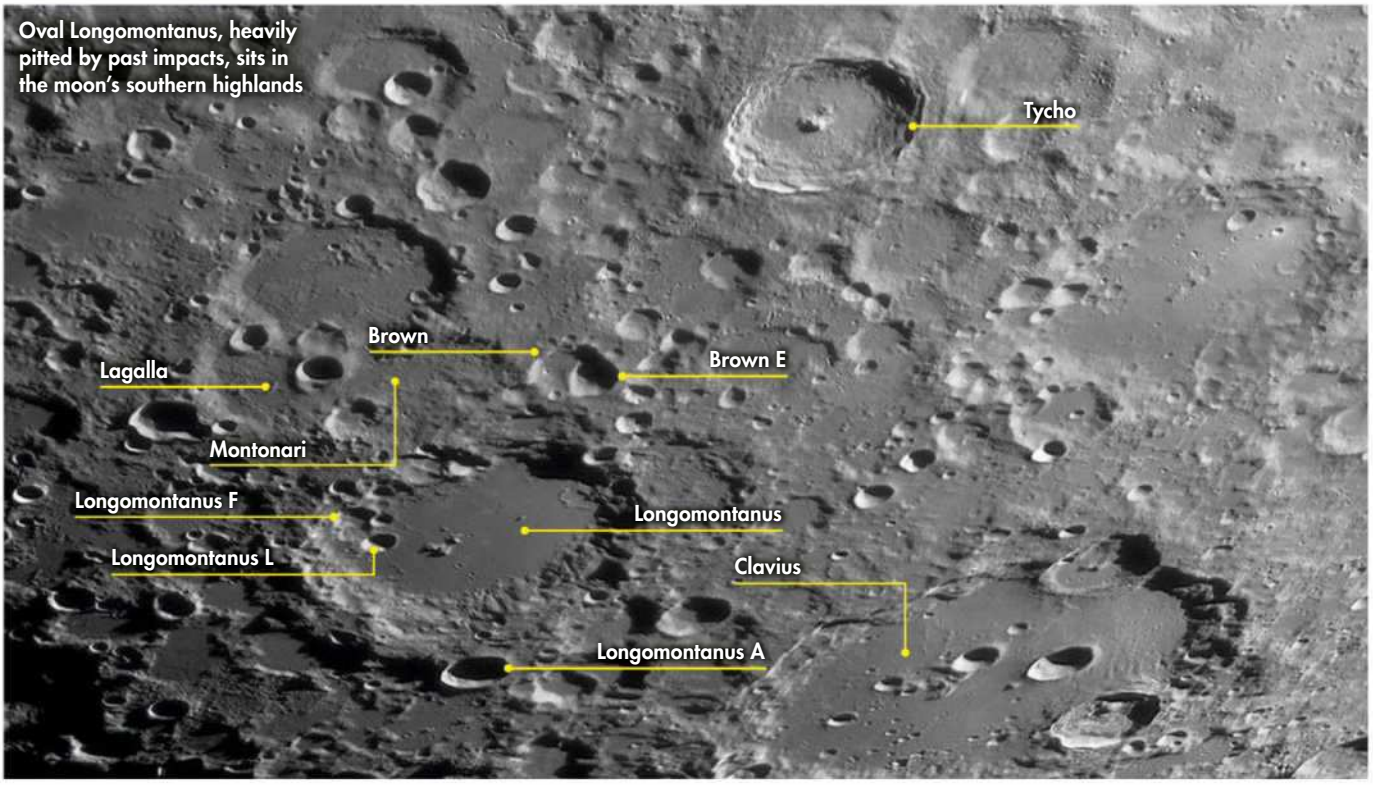
Beautiful Saturn is currently a morning object located in the low southerly constellation of Sagittarius, the Archer. It can be seen to the north of the Teapot asterism which sits at the heart of the constellation, not too far from the star Kaus Borealis (Lambda (λ) Sagittarii) which marks the top of the teapot's lid. Magnitude +0.3 Mars sits very close to mag. +0.9 Saturn on 1 April with the closest approach occurring on the following two mornings when both planets appear separated by 1.3°. A 60% waning gibbous Moon joins the scene on 7 April when Mars, Saturn and the Moon form a line in the sky. By the end of April, mag. +0.7 Saturn almost makes it to its highest point in the sky, due south as the sky begins to brighten.

## Uranus

Uranus is too close to the Sun's glare to be a viable target this month. The planet is in conjunction with the Sun on 18 April.

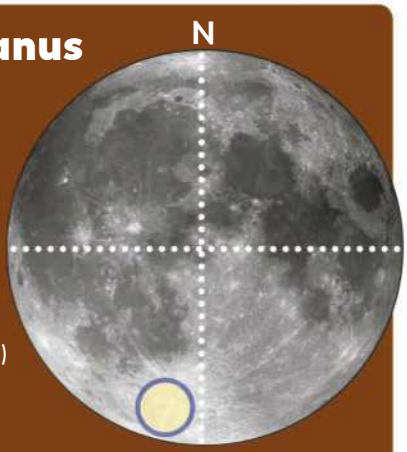
**Not visible this month:** Neptune

**YOUR BONUS CONTENT** Planetary observing forms




# MOON**WATCH**

## Longomontanus




**Type:** Crater
**Diameter:** 146km
**Longitude/Latitude:** 21.9° west, 49.6° south
**Age:** 3.85–3.92 billion years
**Best time to see:** 2 days after first quarter (24–25 April) or 1 day after last quarter (9–10 April)
**Minimum equipment:** 10x Binoculars

PETE LAWRENCE X 3

Longomontanus is a prominent walled plain in the southern highlands. It lies 280km southwest of the bright ray crater Tycho (86km) and 290km northwest of the magnificent 225km diameter crater Clavius. Like Clavius, the floor of Longomontanus is overall quite flat, pock-marked by small craterlets and a cluster of larger craters close to the northwest rim. The northwest rim you'll see is mostly made up of small craters 10–19km in diameter. The largest here is Longomontanus F, with a diameter of 19km and itself having a relatively flat, featureless floor. Longomontanus L (16km diameter) lays closest to what could be loosely termed Longomontanus's central mountain peak complex – there are indeed peaks visible, but they are hardly central to Longomontanus, as they are 86km in from the eastern limb and 58km in from the edge of the western rim. The rim itself appears old, heavily eroded and also impressively high, with peaks of nearly 4km. Despite being very old, the flat floor does manage to stand out remarkably well compared to the complex and somewhat chaotic lunar highland surroundings.

***"The crater's rim is impressively high, with peaks of nearly 4km"***

Longomontanus's ancient floor acts as a screen for more modern events. Examples of this can be seen around some of the tiny craterlets that mark the floor surface. Some of these have bright ejecta, which have not been around long enough to fade and are an indication of much younger activity. On the other hand, there are a number of regions where, with careful scrutiny, it's possible to see vague hints of previous impacts in the region, which have themselves been overwritten by some of the oldest clear features.

An example lies to the north of 29km Longomontanus A, within the rim of Longomontanus itself. Here you can just about make out an additional curved rim some 55km across, which is possibly a previous occupant destroyed when Longomontanus was formed.

Another example lies to the east. Again this appears to be a partial crater overwritten by Longomontanus. This one is large enough to appear almost like an extension of the main crater, as if the upper portions of Longomontanus's rim have been stretched 40km to the east.

The region between Longomontanus and Tycho appears particularly complex, with a small chain of craters around the 15km diameter size range. Some are labelled as satellites of Longomontanus, some belong to 35km Brown, which sits just to the northeast of Longomontanus, and some belong to Tycho. Brown is another old crater but, being smaller, holds its form relatively well – that is, apart from the impressive interruption to the southeast, where 22km Brown E overlaps roughly a third of Brown.

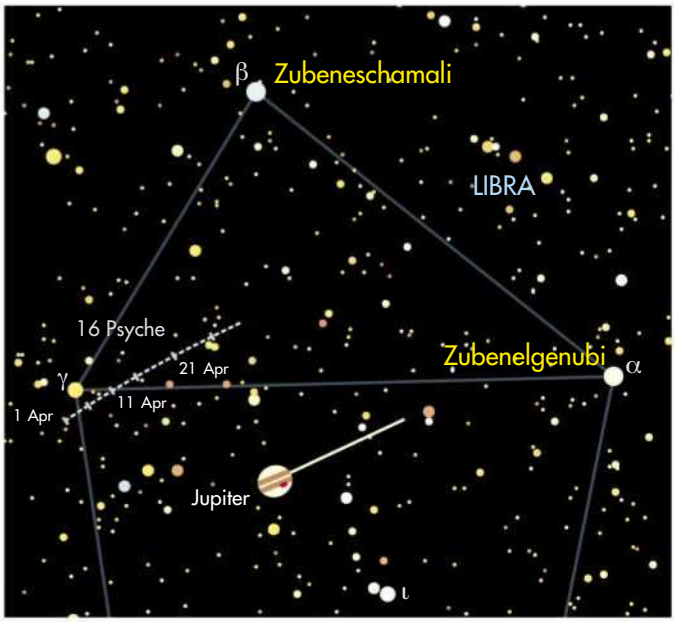
Immediately to the north of Longomontanus is a particularly eroded crater, 78km Montanari. It's not even clear where the western edge of Montanari is as the crater seems to blend seamlessly into another ancient feature, 86km Lagalla to the northwest.

# COMETS AND **ASTEROIDS**

## Massive, metallic, potato-shaped 16 Psyche should be visible all month

This month's featured asteroid is 16 Psyche, chosen because it is currently relatively easy to locate and appears to be keeping track with Jupiter in the constellation of Libra. It starts the month as a mag. +11.1 object located reasonably close to mag. +3.9 Gamma (γ) Librae. It undergoes a slight brightening to mag. +10.6 by the end of the month, so it should be a small telescope target throughout April. Psyche will reach opposition on 10 May, when it will appear to shine at mag. +10.4.

Psyche is an interesting object. It is 200km in diameter and thought to be the iron core of a protoplanet – a body formed out of the Solar System's proto-planetary disc, which had enough mass to undergo internal melting and deformation. As a consequence, Psyche is quite massive, ranking as one of the 10 most massive asteroids known. Its gravitational influence on other asteroids has been used to accurately determine its mass as $2.72 \times 10^{19}$kg.




▲ **Asteroid 16 Psyche will be well placed for observation in Libra**

Psyche takes 4.99 years to complete one orbit of the Sun at an average distance of 2.9 AU. Its orbit brings it as close as 2.5 AU to the Sun and out as far as 3.3 AU. It rotates once on its axis every 4.2 hours. Psyche is not a spheroid, being more a potato-shape at 279 x 232 x 189km. Its size and shape were partly calculated by compiling the results of over 100 occultation events involving distant stars, taken together to help build a 3D model of the body. Further observations using radar and specialist optical setups then helped to refine the shape we believe Psyche to be today.

Observations carried out in 2016 by NASA's 3m Infrared Telescope Facility (IRTF) on Mauna Kea in Hawaii produced results indicating the presence of water on Psyche, possibly having been delivered following impacts from smaller bodies in the past.

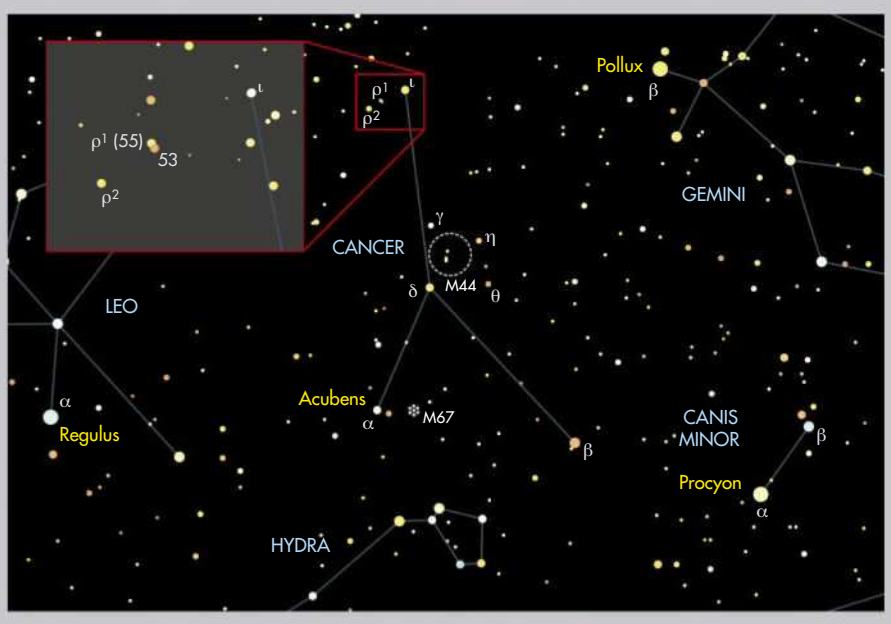
# STAR OF **THE MONTH**

## 55 Cancri and its record-breaking exoplanets

55 Cancri ($\rho^1$ Cancri) is a mag. +5.9 star on the threshold of naked-eye visibility from a typical dark sky site. The best way to locate it is to first look for mag. +4.0 Iota (ι) Cancri, marking the northern end of the inverted Y-shape of Cancer.

Two degrees west of Iota sits mag. +5.2 $\rho^2$ Cancri, more likely to be seen with the naked eye than $\rho^1$. Using binoculars, our target star is the northernmost of a close pair of stars located two-thirds of the way from Iota towards $\rho^2$. This pairing is false as $\rho^1$, at 40.3 lightyears, is just a fraction of the 894 lightyear distance of its 'pair', the mag. +6.3 53 Cancri.

55 Cancri is a true binary, consisting of a G-type star, 55 Cancri A, with a 13th magnitude red dwarf companion, 55 Cancri B. The spectral type of 55 Cancri A is G8V, slightly cooler and redder than the G2V classification of our own Sun. Physically, there are further similarities as 55 Cancri A has a diameter and mass equal to 96% of the Sun. Its luminosity is around 59%, with a temperature of 5,165K compared to 5,778K for the Sun. 55 Cancri A's age is difficult to determine, with estimates ranging between 7.4–12.7 billion years – far older than the Sun's 4.6 billion years. Most excitingly, the star has a planetary system consisting of five or possibly more planets, several within its habitable zone. Any moons existing around them, if sizeable enough, could play host to simple microbial life.




▲ **55 Cancri is located in the northern part of Cancer, the Crab and is nicely seen with binoculars**

In 2014 the International Astronomical Union (IAU) asked the public to help name certain exoplanets and their parent stars. As a result, 55 Cancri A is also known as Copernicus and the five known planets, in order of distance from Copernicus, are Janssen (e), Galileo (b), Brahe (c), Harriot (f) and Lipperhey (d). A message beamed to the system on 6 July 2003 is set to arrive in May 2044.

## STEPHEN TONKIN'S
# BINOCULAR **TOUR**

This month, beautiful blue diamonds, a ride on a coaster and bird-spotting in Cassiopeia

☑ Tick the box when you've seen each one

## 1 MELOTTE 20

10x 50 Also known as Alpha Persei Moving Cluster, this is a stunningly beautiful binocular target, extending as it does for over 3°. It extends nearly 4° southeast from mag. +1.8 Mirphak (Alpha (α) Persei). It is an association of mostly hot young blue (spectral types O and B) stars which, in binoculars, sparkle like diamonds on black velvet. Only about 60 million years old, the cluster is called 'moving' because all the stars share a similar proper motion (motion relative to the celestial sphere) of around 33 milliarcseconds per year. ☐ **SEEN IT**

## 2 BETA CAM

10x 50 Beta (β) Camelopardalis is visible to the naked eye at mag. +4.0. Its mag. +7.4 companion is a very easy split, even in small binoculars, 84 arcseconds to the southwest, but this is not the main appeal of this star. Beta Cam is classified as a yellow supergiant, which is relatively young at 40 million years old and in transition between being a hot new blue star and a red supergiant. Enigmatically, it has been seen to brighten by a whole magnitude in a flash with a duration of ¼ second, possibly its equivalent of huge solar flares. ☐ **SEEN IT**

## 3 STOCK 23

10x 50 If you pan slightly more than 1½° due west from magnitude +4.3 CS Camelopardalis, you will find an unremarkable little trapezium of 7th and 8th magnitude stars. This is Stock 23, also known as Pazmino's Cluster. With 50mm binoculars you can see this is much more than a trapezium and you may be able to resolve about half a dozen stars against a faintly glowing patch of sky about 10 arcminutes in diameter. ☐ **SEEN IT**

## 4 EDDIE'S COASTER

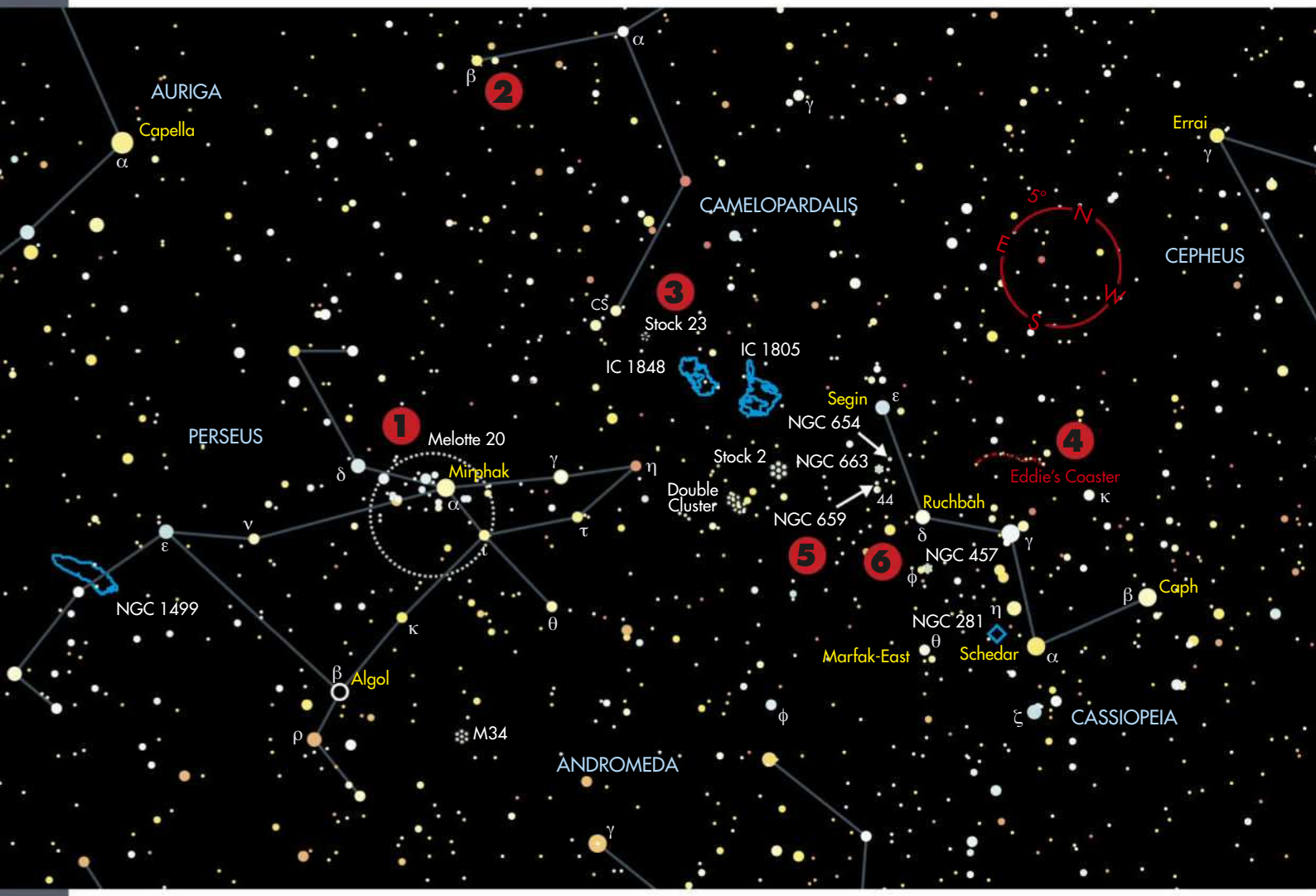
10x 50 One of the 'binocular classics', Eddie's Coaster is an asterism that is not easily apparent in star charts or photographs, but is very obvious in 10x50 binoculars. To find it, look 3° north of Gamma (γ) Cassiopeiae, where you will find a 3°-long wave of 7th and 8th magnitude stars, reminiscent of a roller-coaster, hence its name. ☐ **SEEN IT**

## 5 THE CASSIOPEIA TRIPLE CLUSTER

15x 70 Look 1° to the left (east) of the middle of an imaginary line joining Segin (Epsilon (ε) Cassiopeiae) and Ruchbah (Delta (δ) Cassiopeiae) and you will easily find the largest and richest of these clusters, NGC 663. The four brightest stars appear to be separated into pairs by a dark lane. Just shy of 1° to the north-northwest is the brighter but smaller NGC 654. The poorest of the trio is NGC 659, a tiny ghostly glow which may need averted vision, just on the NGC 663 side of the mag. +5.8 star 44 Cas. ☐ **SEEN IT**

## 6 THE OWL CLUSTER

15x 70 Using Ruchbah as your jumping-off point, identify mag. +4.3 Marfak-East (Theta (θ) Cassiopeiae) and navigate 2° towards it, where you'll find an easy double star with its components shining at mag. +5.0 and +7.0, separated by 135 arcseconds. These are the owl's eyes. Its body and wings are composed of 9th and 10th magnitude stars that span an area about ¼ ° in the direction of Gamma Cas. The brighter eye, Phi (φ) Cassiopeiae, is not actually part of the cluster: it lies just over half way from us to NGC 457, which is nearly 8,000 lightyears distant. ☐ **SEEN IT**



# THE SKY GUIDE **CHALLENGE**

## With some simple props, isolate and capture the shadow cast by Venus

From Earth, Venus appears intensely bright shining away in the evening or morning twilight sky. If you catch it right, it can also be seen against a dark sky, but the conditions for this can be tricky to achieve. If the sky is dark enough, the intense light from Venus can do something obvious but still rather amazing – it can cast a shadow. This month's challenge is to photograph the shadow cast by Venus.

Venus's light may be intense, but there's not much of it. Consequently, any other light will swamp it completely. One way to overcome this is to create an environment where the light from Venus is dominant. One way of doing this is to make use of a room or an area inside a house where there's a window facing in the correct direction and which will let light from Venus enter and fall on a building wall. If this isn't feasible, another technique is to create an artificial 'room' – say with a cardboard box – that can be positioned in such a way that a single opening points at Venus. Both methods require a target that will be used to make the shadow. This can be anything you like, such as a shape cut from card attached to a window or, in the case of the cardboard box, suspended in the opening. The shape we opted for was the symbol for Venus.

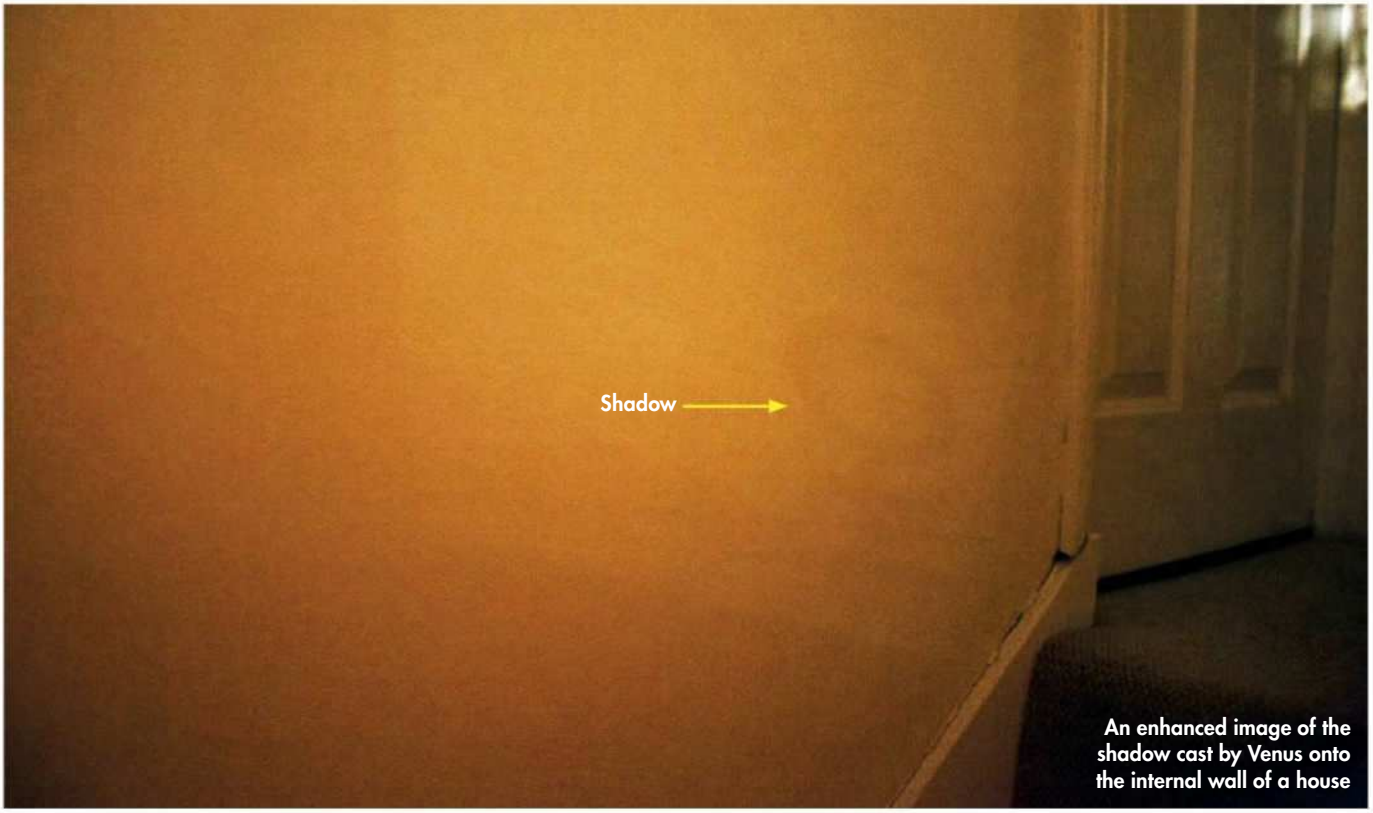
Finally, the 'screen' wall will work better if it is smooth and white. A piece of white paper or card is ideal for this. This can be temporarily attached to a wall or stuck to the surface of the box opposite the opening.

The target for our shadow image was the symbol for Venus cut out of card. Distant trees also created a mottled effect in the final animation

To show the shadow at its best, a good technique is to create an animation of the shadow moving as Venus appears to set. A DSLR camera on a tripod is good for this, but any camera that allows a high ISO and multi-second exposure should work too.

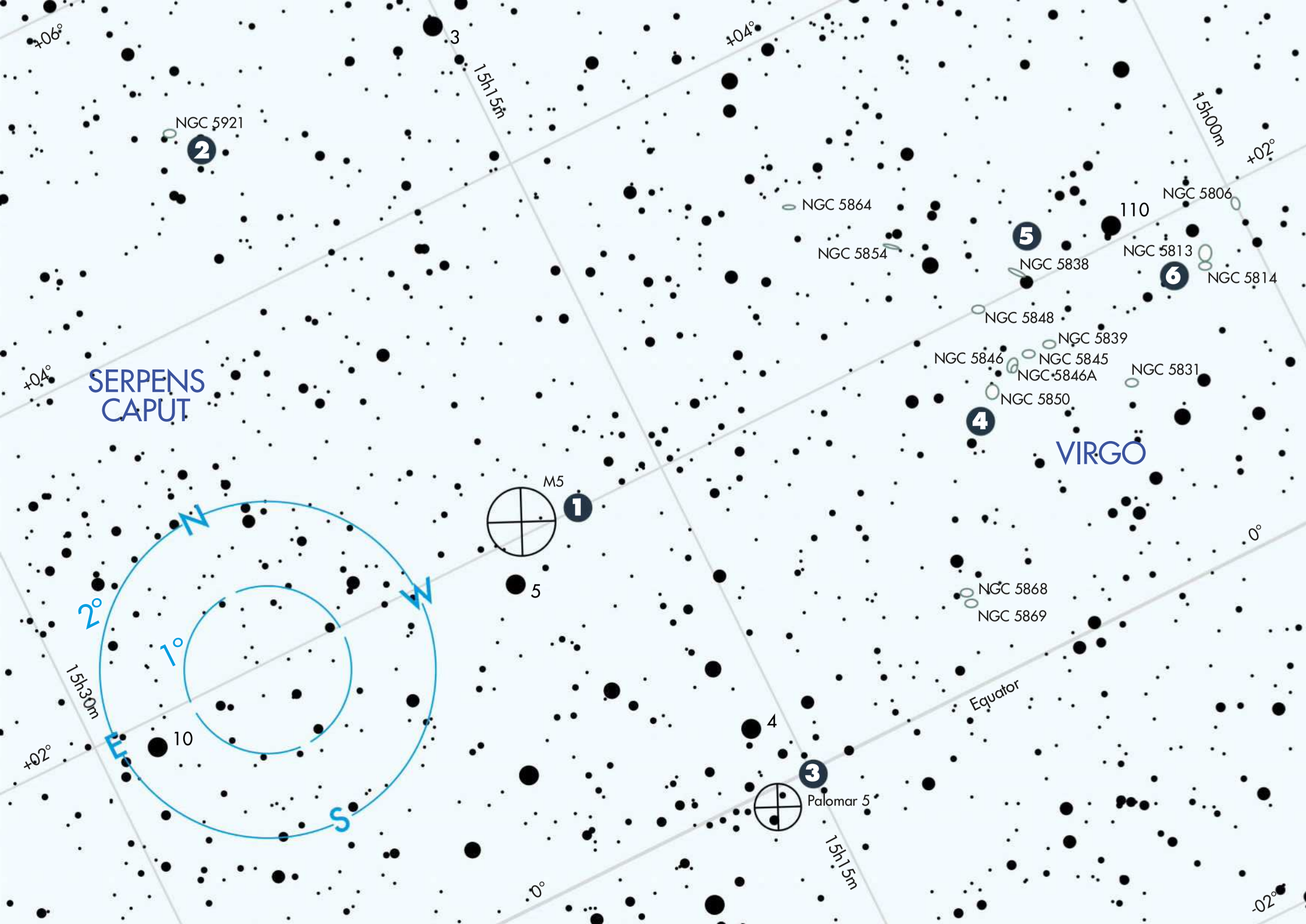
Set everything up on a clear evening. Imagine where the light from Venus will be falling and casting the shadow – basically a straight line from Venus through the target and onto the screen. Set a high ISO, fully open the lens and aim to use an exposure of 10–30 seconds. Focus on the screen carefully. You may want to temporarily illuminate it to do this accurately.

Take the first image. Wait one minute and then repeat. Flicking between the two images should be enough to reveal the weak shadow. The shadow is incredibly sharp because Venus is effectively a point source of light. However, the longer your exposure, the fuzzier the shadow will become because its edges are essentially moving.




An enhanced image of the shadow cast by Venus onto the internal wall of a house

PETE LAWRENCE X 3


+06°
3
15h15m
+04°
15h00m
+02°
NGC 5921
2
NGC 5864
NGC 5806
110
5
NGC 5854
NGC 5838
NGC 5813
6
NGC 5814
NGC 5848
NGC 5839
NGC 5846
NGC 5845
NGC 5846A
NGC 5831
NGC 5850
4
SERPENS CAPUT
VIRGO
M5
1
5
N
W
2°
1°
15h30m
E
10
S
4
3
Palomar 5
Equator
0°
NGC 5868
NGC 5869
15h15m
-02°

# DEEP-SKY TOUR

## Surfing the galaxies and globulars around Serpens Caput and Virgo

☑ Tick the box when you've seen each one

### 1 M5

M5 is a magnificent example of a globular cluster and, for some, the finest in the northern sky. It has a visual magnitude of +5.6 and is located in Serpens Caput close to the border with Virgo. It is easily located by extending a line from mag. +5.0 CU Virginis through mag. +3.7 109 Virginis for the same distance again. M5 also lies 22 arcminutes northwest of mag. +5.0 5 Serpentis. A 150mm scope shows a 10 arcminute glowing mass of stars, many resolved with increasing magnification. A number of stars appear to form strings running out from the core. Large telescopes at high power show a bright, grainy core which fills one-quarter of the cluster's overall size.
☐ **SEEN IT**

### 2 NGC 5921

We remain in Serpens Caput for our next target, a mag. +10.8 galaxy known as NGC 5921. This is located 3° north and 0.8° east of M5 and similarly has a nearby star to guide the way. In this case, it's a ninth magnitude star 2.9 arcminutes to the southeast of the galaxy. A small instrument shows NGC 5921 as a circular glow with a 12th magnitude star on its southwest edge. Larger instruments show that this star appears to belong to a group of four which form an arc guiding you toward the galaxy. Larger instruments also show the galaxy to be elongated with an extended core.
☐ **SEEN IT**

### 3 PALOMAR 5

Palomar 5 is a mag. +11.8, challenging globular that was discovered by the German astronomer Walter Baade in 1950. It is located in Serpens Caput, approximately 2.3° south-southwest of M5 and, like the previous targets, also has a nearby 'guide-star' in the guise of sixth magnitude 4 Serpentis, 0.5° north. A large aperture is required and with magnifications under x100 it's difficult to detect anything of this 8 arcminute object. If you do manage to see it, the cluster appears as a large, faint patch of light. The best viewing technique is to use averted vision. Palomar 5 is 76,000 lightyears away and estimated to be 11.5 billion years old.
☐ **SEEN IT**

### 4 NGC 5850

We hop across the border into Virgo for our next target, the galaxy NGC 5850. This lies 2.8° west and 0.5° south of M5. It's also fairly close to the mag. +4.4 star 110 Virginis, 1.2° to the west-northwest. This 11th magnitude galaxy belongs to the 5846 group. A 150mm telescope will just show it sitting 10 arcminutes south of the 11th-magnitude galaxy NGC 5846. NGC 5850 looks quite elongated through larger instruments, with a core that appears to stand out well from a fainter halo, but overall the concentration isn't that well defined. While viewing, a star-like nucleus seems to pop in and out of vision. Larger instruments still show the core as an extended feature thanks to two large and very faint glowing regions on either side of it. Overall this makes the core look three times longer than it is wide.
☐ **SEEN IT**

### 5 NGC 5838

Our next target on this month's deep-sky tour is 11th-magnitude NGC 5838. This is another spiral galaxy located 0.75° to the northwest of NGC 5850. NGC 5838 appears as a small object approximately 1 arcminute across through telescopes below 250mm aperture. Smaller instruments also show the central nucleus of the galaxy as quite stellar in appearance. As your aperture increases, more of its detail is revealed and the outer halo appears elongated in shape. A 300mm instrument reveals the galaxy's core as a circular affair surrounded an outer halo approximately 2.5x1.0 arcminutes in size. As with our last object, this galaxy is another member of the NGC 5846 group.
☐ **SEEN IT**

### 6 NGC 5813

We finish this month's tour with one final galaxy and another member of the NGC 5846 group. NGC 5813 is an 11th magnitude elliptical galaxy in Virgo. Visible in a 150mm scope, it lies just over 1° west-southwest of NGC 5838. It's conveniently framed by three 12th magnitude stars along its southern and eastern edges. Larger instruments bring a fourth, mag. +13.3, framing star into view to the north. The galaxy appears elongated and around 1x0.5 arcminutes in size, with a stellar nucleus. Increasing aperture makes the overall galaxy appear larger and the core take on a less stellar appearance, having a now more pronounced, elongated shape.
☐ **SEEN IT**

**THIS DEEP-SKY TOUR HAS BEEN AUTOMATED**

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

◂ **Elongated NGC 5921, with a glowing arc of four stars on its southwest edge**

**YOUR BONUS CONTENT**

**Print out this chart and take an automated Go-To tour**

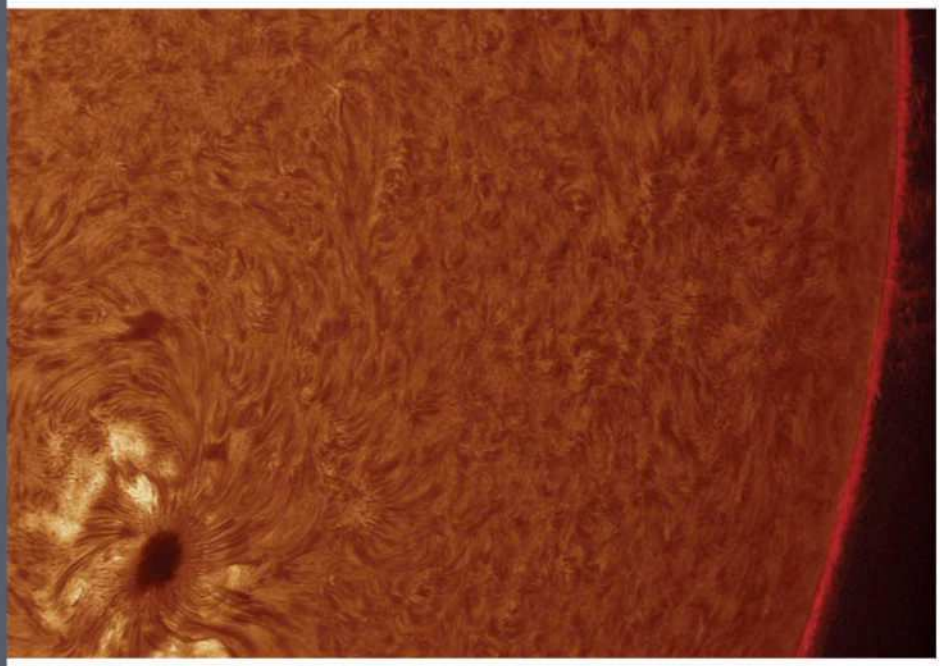
CHART: PETE LAWRENCE, PHOTO: MICHAEL BREITE/ STEFAN HEUTZ/ WOLFGANG RIES/CCDGUIDE.COM

# ASTROPHOTOGRAPHY

## Imaging the Sun in h-alpha

### RECOMMENDED EQUIPMENT

H-alpha-enabled telescope, mono high frame rate camera



▲ **H-alpha view of the Sun, showing the exquisite magnetic complexity near an active region**

The Sun in h-alpha is a glorious thing. Although suitable filters are quite expensive, their price has come down considerably and many now have access to this equipment either through direct ownership or via clubs and societies.

The expense comes down to the fine tolerances to which these filters have to be made. Essentially, they need to permit a very narrow set of wavelengths centred on 656.28nm to pass through. When this is achieved, the view is exhilarating. All wavelengths of light are blocked except that associated with the principle emission line of excited hydrogen atoms in the visible part of the spectrum. Suddenly, the relative quiet of the white light Sun is transformed into a seething mass of hydrogen plasma contorted by complex magnetic fields.

The Sun's photosphere appears covered by a blanket of writhing hydrogen which gives a mottled surface not unlike the appearance of an orange. This is the solar chromosphere, a layer invisible under normal white light conditions. Typically, the chromosphere is crossed by one or more dark snaking lines, known as filaments. As the Sun rotates on its axis, new filaments may be brought into view as existing ones rotate out of view around the western limb. These features are suspended clouds of cooler hydrogen, supported by immense magnetic fields. As they are dragged into and out of visibility around the Sun's limb they appear suspended above the chromosphere and are known as prominences.

**WARNING**
**Do not look directly at the Sun with the naked eye or any unfiltered optical instruments**

Active regions take on a whole new appearance in h-alpha. The dark cores of sunspots are often fairly well camouflaged against the chromosphere. Short, dark lines known as fibrils pick out the intense magnetic field lines around the region. Bright flares may also show in larger and more active groups.

Capturing these features at their best requires a monochrome, high frame rate camera setup. H-alpha light is essentially monochrome itself, so the use of a colour camera is inefficient. Once fitted, a few checks are necessary to make sure you get the best view. In addition, there are several tricks that can be employed to improve that view further.

H-alpha filters require a very accurate spacing between the filter elements. Differences in temperature or pressure can detune a filter so you're not getting the best view. As part of the initial setup process, it's worth taking time out to adjust the filter's tuning mechanism – if available – to optimise the view.

Although modern filters are able to provide a wide field of view with reasonable consistency, a large camera chip may challenge the filter's ability to maintain an even field. Here, a trick from deep-sky astrophotography known as flat-fielding can be employed. Flat-fielding is normally done by pointing a telescope at a source of even illumination without having altered the camera's orientation or focus position. When generating a flat for a h-alpha shot, as long as the image scale allows the camera's chip to be completely covered with chromosphere, it's possible to take a suitable flat by breaking the deep sky rule and defocusing the image. It's amazing how well this simple procedure works towards producing a far cleaner, gradient-free image.

Our step-by-step guide on the page opposite gives you the low-down on how to capture and present your results at their best. All you need now is to get set up and for the Sun to shine!

### KEY TECHNIQUE

**CHROMOSPHERE CLOSE-UP**

The Sun offers us the unique opportunity to study a star in close-up. With a white light filter fitted, you can observe and image the Sun's visible surface or photosphere just as you would, say, the surface of the Moon. However, to really see what the Sun has to offer, nothing beats the view through a hydrogen alpha (h-alpha) filter. A monochrome camera works best with h-alpha light, but considerations need to be made in order to obtain a practical image scale and to 'see' the features on view optimally. Unlike the view in white light, h-alpha features can also have a tendency to change quite quickly.

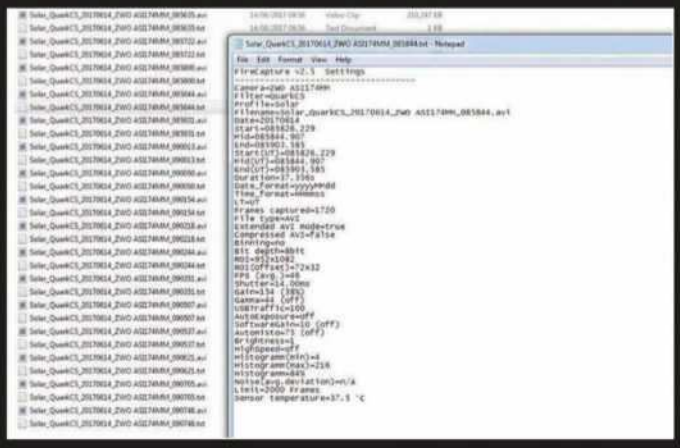
**Send your images to: hotshots@skyatnightmagazine.com**

ALL PICTURES: PETE LAWRENCE

# STEP BY STEP


## STEP 1

With a camera inserted, point your h-alpha filtered scope at the Sun. Maintain neutral gamma and select a fast frame rate. Adjust the gain to give an exposed view of the disc with saturation levels around 80-90%. If gain goes above 75%, select a slower frame rate and readjust. If available, tune the filter to achieve a view with the highest contrast.

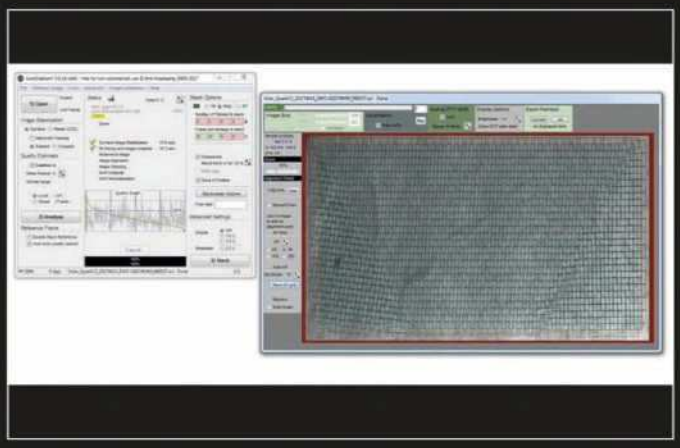


## STEP 2

Make a capture, typically grabbing 1,000–1,500 frames. It's a good idea to set your capture software to record a log file against each capture and to stamp date, time and filter name into each filename. Make sure your laptop's clock is correct and that the timestamps are recorded as UT. Make a capture of all interesting 'surface' features as required.

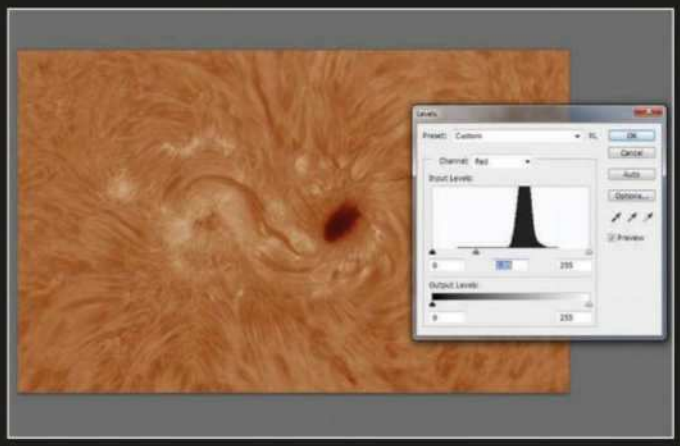
## STEP 3

If your image scale is such that you can only fit part of the surface into the field of view at a time, then it's possible to clean up unwanted image gradients or dust by creating a flat field (shown here). With the entire frame filled with the Sun, defocus until no features can be seen. With saturation set around 70%, make a 500–1,000 frame capture.



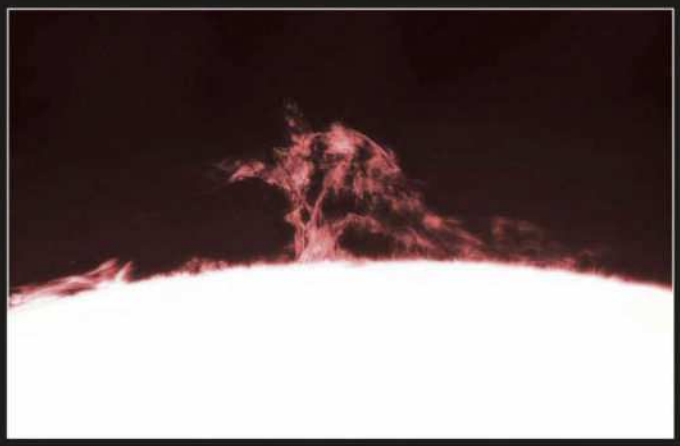
## STEP 4

In AutoStakkert, open the flat-field capture and process using Image Calibration – Create Master Frame. Use Load Master Flat to load it. Open a surface capture. Click Analyse. Use Frame Percentage to Stack values of 20 and 30. Select a small AP (alignment point) size, click Place AP Grid. Click Stack. Your final images will be in the capture file folder.



## STEP 5

Final images can be sharpened and adjusted using your preferred editor. Don't overdo sharpening. False colour is commonly applied to monochrome images. Make sure you're in RGB mode. Using Levels: move the R midpoint towards black, G and B midpoints towards white. Tweak until you get a reddish-orange colour. Save the settings for reuse.



## STEP 6

Adjust the frame rate/gain to bring prominences into view. This typically requires the chromosphere to appear close to saturation or over-exposed (white). Flat fields won't work for off limb features. Keep captures relatively short to avoid motion blur from fast-moving prominences. Increasing the gamma may help bring fainter features into better view.

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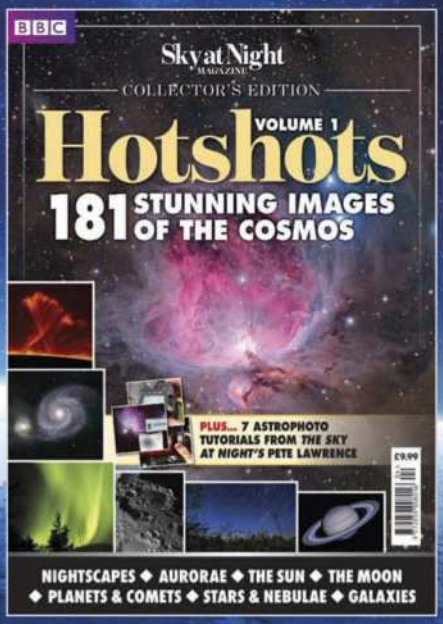


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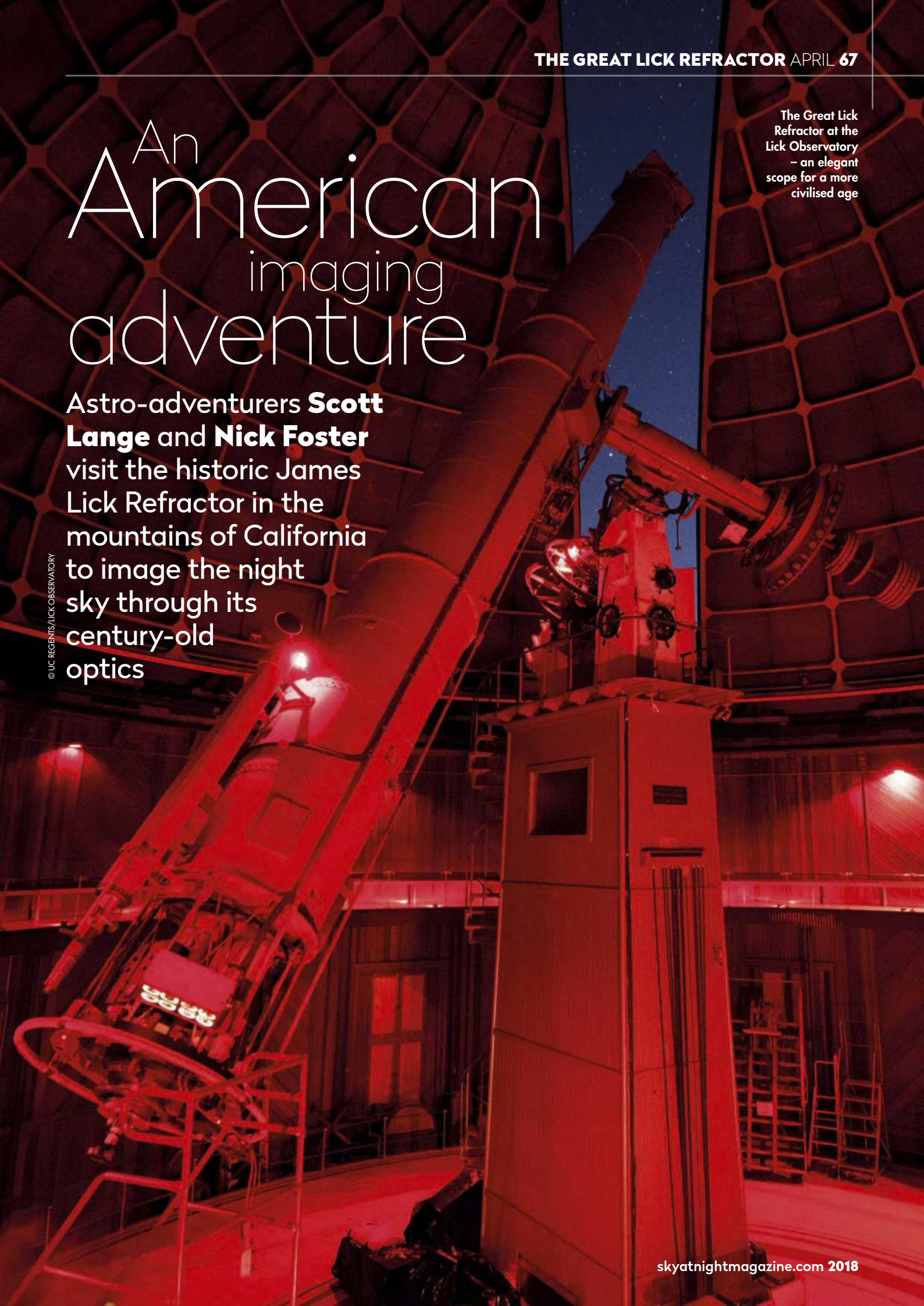
# An American imaging adventure

Astro-adventurers **Scott Lange** and **Nick Foster** visit the historic James Lick Refractor in the mountains of California to image the night sky through its century-old optics



The Great Lick Refractor at the Lick Observatory – an elegant scope for a more civilised age

During 2017 we journeyed to the Californian hills to capture the cosmos through the 129-year-old Great Refractor at the Lick Observatory, 120km south of San Francisco. Our goal? To point this historic telescope towards some of our favourite targets and capture its antique observing power through the eyes of a modern DSLR camera.

A contact at the University of California, Santa Cruz put us in touch with the Lick Observatory staff, and once we explained the nature of our project, they too were intrigued at the prospect of using this mighty telescope to capture deep-sky images with a contemporary camera.

We quickly learned that the cost to operate the 19th century relic would be significant, so we launched an overwhelmingly successful Kickstarter project to fund this astronomical madness. We were able to make four, three-hour trips to the observatory during the year, and much planning was required to ensure we could capture quality astro images while allowing for the steep learning curve of getting to know our way around the historic instrument.

The Lick Observatory was the brainchild of James Lick, born in Stumpstown (now Fredericksburg) Pennsylvania, on 25 August 1796. After making his fortune in the housing boom of San Francisco, spurred on by the California Gold Rush of the mid-1800s, Lick decided to spend his money building one of the largest telescopes of the era, in the world's first mountaintop observatory.

▲ **The Lick Observatory was built atop Mount Hamilton in California (at an altitude of 1,280m), and is accessed by a very windy road**

## Classic, elegant craftsmanship

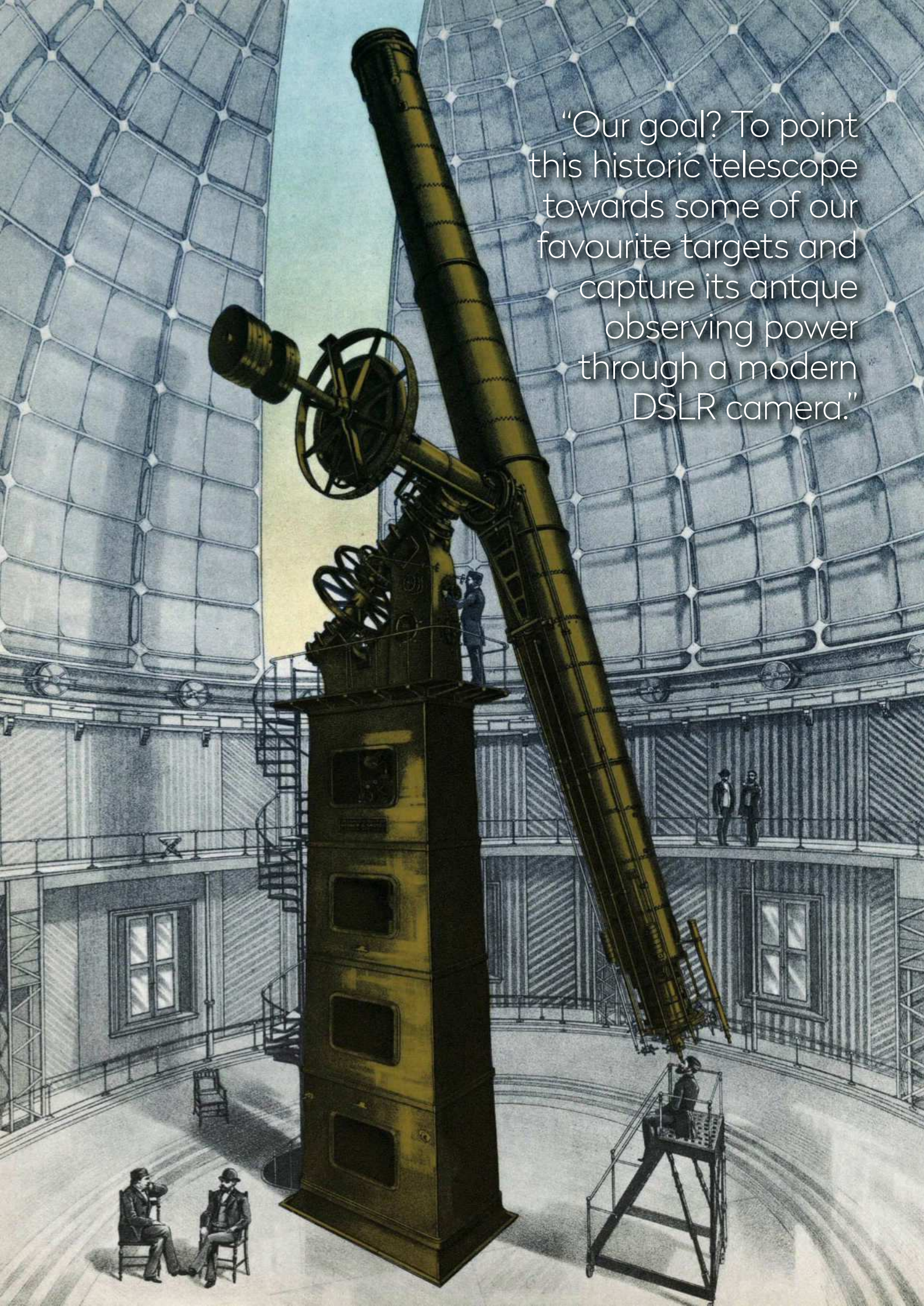
When navigating the narrow trail to reach the observatory today, you get a feel for how tough its construction must have been. The steep road up Mount Hamilton climbs into California's Diablo Range just east of San José, and although it's only about 40km from the base of the mountain, it takes roughly an hour to traverse the windy mountain trail. However, the route provides some amazing views of the Santa Clara Valley along the way.

The Great Lick Refractor is something we were both already familiar with, having visited the telescope in the past and taken a tour of the observatory. We were mesmerised by its history and the craftsmanship behind its construction: particularly the fact that the instrument is 17m long with a whopping 1m aperture! Looking through ▸

► **A drawing from 1889 – the year after the Great Lick Refractor achieved first light – designed to emphasise the massive scale of the project**

▼ **The view from the Observatory looking down from the Diablo Range towards San José**

SILICONVALLEYSTOCK/ALAMY STOCK PHOTO, STARS AND STRIPES/ALAMY STOCK PHOTO, SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO



"Our goal? To point this historic telescope towards some of our favourite targets and capture its antque observing power through a modern DSLR camera."

# New meets old: astro imaging created by classic and modern tech combined

**A selection of images taken by Scott and Nick at the Lick Observatory. The refractor's tracking abilities limit exposures to around 30 seconds – which restricts light collection – but its huge 1m aperture compensates**

## △ Jupiter

"The brightness of Jupiter made it an easy target for the massive refractor's telephoto focal length, although the chromatic aberrations from the 129-year-old lens caused the planet to appear slightly burry," says Scott.

## ◁ M15

"Messier 15 is one of the oldest known globular clusters at an estimated 12 billion years old. These clusters lie in the halo of our Galaxy and contain some of the oldest stars ever studied. The different colours of the stars correspond to each one's age, temperature and size."

## The Moon ▷

"The first quarter Moon was one of the most exciting objects to view with the Great Lick Refractor. The extreme focal length of the giant telescope brings the observer right to its surface, enabling you to see the stark depth and light contrast of the terminator."

## ◁ The Blue Snowball Nebula

"This distant planetary nebula would appear as just a very tiny spec through most telescopes, making it a great target to test the instrument's mighty focal length. Planetary nebulae resemble what our Solar System might look like when the Sun dies."

SCOTT LANGE/NICK FOSTER X 8, GRANGER HISTORICAL PICTURE ARCHIVE/ ALAMY STOCK PHOTO © UC REGENTS/LICK OBSERVATORY, DR ELINOR GATES

▸ a regular 2-inch eyepiece at the end of the Great Lick Refractor is a real treat, but we were excited to have the opportunity replace that eyepiece with our Canon EOS 6D DSLR camera to see how well the two would combine to image the night sky.

The telescope tube is so long that, in order to view objects near the horizon, the entire observatory floor has to be hydraulically raised so you can access the eyepiece. Its antique controls, oversized gauges and brass finishing make you feel like you're aboard one of Jules Verne's extraordinary craft. Adding to this illusion are the hand wheels on the main telescope focus and the mount controls that were built by the 19th century US manufacturers Warner & Swasey Co, both of which resemble steering wheels on old vessels. You can easily drop a regular eyepiece into the 11,400kg telescope, and while the 129-year-old lens has its imperfections, its light-capturing power can still leave observers in awe.

## Tricky tracking

Imaging with the Great Lick Refractor using a modern day DSLR camera proved to be a rewarding feat. While the tracking isn't as good as many consumer telescopes available today, this doesn't really matter because the power of the lens provides

## ◁ The Ring Nebula

"This was one of our most sought-after objects for this project: when we had imaged it before with our own 8-inch Newtonian, it appeared as a tiny dot in the frame. The extremely high focal length brought this planetary nebula up close and personal."

## M3 ▷

"Messier 3 is a globular cluster in Canes Venatici. We had to get used to the stars not appearing as pin-pointed as we're used to with modern equipment, because of the 'zoomed-in' nature of the Great Lick Refractor's roughly 17,000mm focal length, along with its lens aberrations."

## ◁ M1, The Crab Nebula

"This supernova remnant proved difficult to image as the nebula's surface brightness is relatively low and the Great Lick Refractor's tracking limitations only allow for relatively short exposures – which is far from the ideal combination for the antique telescope's capabilities."

## NGC 7331 ▷

"A spiral galaxy similar in size and structure to our own, this one is often referred to as 'the Milky Way's twin'. The faint nature of distant galaxies makes them hard to image with short exposure times, so we boosted the brightness on the final product to reveal more detail."

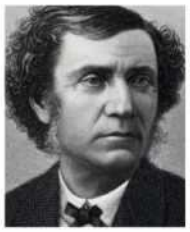
**ABOUT THE WRITERS**

**Scott Lange (left) and Nick Foster are astro imagers who travel the world looking for astronomy adventures.**

plenty of photons, even with short exposures of 20 to 30 seconds. The lens does suffer from some chromatic aberrations, which means that it bends the red and blue wavelengths of the light spectrum slightly out of sync, causing them to look a bit blurry. But frankly, this is a trivial problem in the grand scheme of things. After all, standing in the grounds of this historic building, observing ancient light from distant galaxies through a titanic 129-year-old refractor and capturing them on a digital camera is enough to make anyone marvel at the prowess of human endeavour, and the wonders of the Universe around us.

# From gold rush to GALAXIES

**James Lick was a businessman with a vision that stretched far beyond Earth**

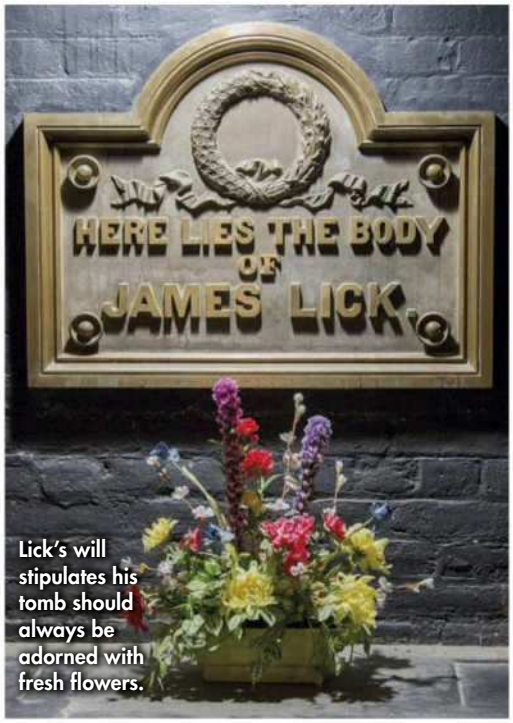


James Lick was the son of a carpenter who followed his father's trade, eventually becoming a master piano maker. In 1848, Lick made his way to the small village of San Francisco and began buying real estate. Shortly thereafter, gold was found near Sutter's Mill and the California Gold Rush began.

While Lick did try his luck in the gold mines, he decided that real estate was a more suitable calling. The housing boom that followed the Gold Rush made him the wealthiest man in California.

As he was always interested in science, especially astronomy, in 1875 he donated $700,000 to build an observatory atop 1,300m Mount Hamilton and equip it with the largest, most powerful telescope on the planet. This would prove to be an engineering feat of monumental proportions, as first a hand-built road had to be constructed up the rugged mountain. Then, piece-by-piece, the telescope components were trekked up the mountain by horse and carriage.

Troubleshooting with the telescope and massive lens had to be done on-site, which proved to be difficult given the limited accessibility and cold temperatures. Construction took place from 1880 to 1888, but Lick had already passed away in October 1876 before work had even begun. The great telescope builder was buried in a tomb at the base of the mammoth instrument, where he lies today, a brass plaque bearing the simple inscription, "Here lies the body of James Lick".




**Lick's will stipulates his tomb should always be adorned with fresh flowers.**

# Touched by genius

## John Wall: 26.06.1932 – 27.01.2018

**Martin Dawson** remembers the life of his friend John Wall, the design engineer, amateur astronomer and inventor of the Crayford Focuser

John Wall was born in Crayford, Kent on 26 June 1932. A year later his parents moved to Dartford, where John lived for the next 60 years.

John's early life was turbulent – the Second World War broke out when he was seven and he was evacuated to Launceston, Cornwall. In 1942 he returned to Dartford after the worst of the Blitz, but experienced many air raids and witnessed a doodlebug fall a quarter of a mile from the family home.

It was while John was at secondary school that his interest in engineering and astronomy blossomed. He left school in 1947 aged 15 and joined Vickers Engineering as a shop boy and apprentice.

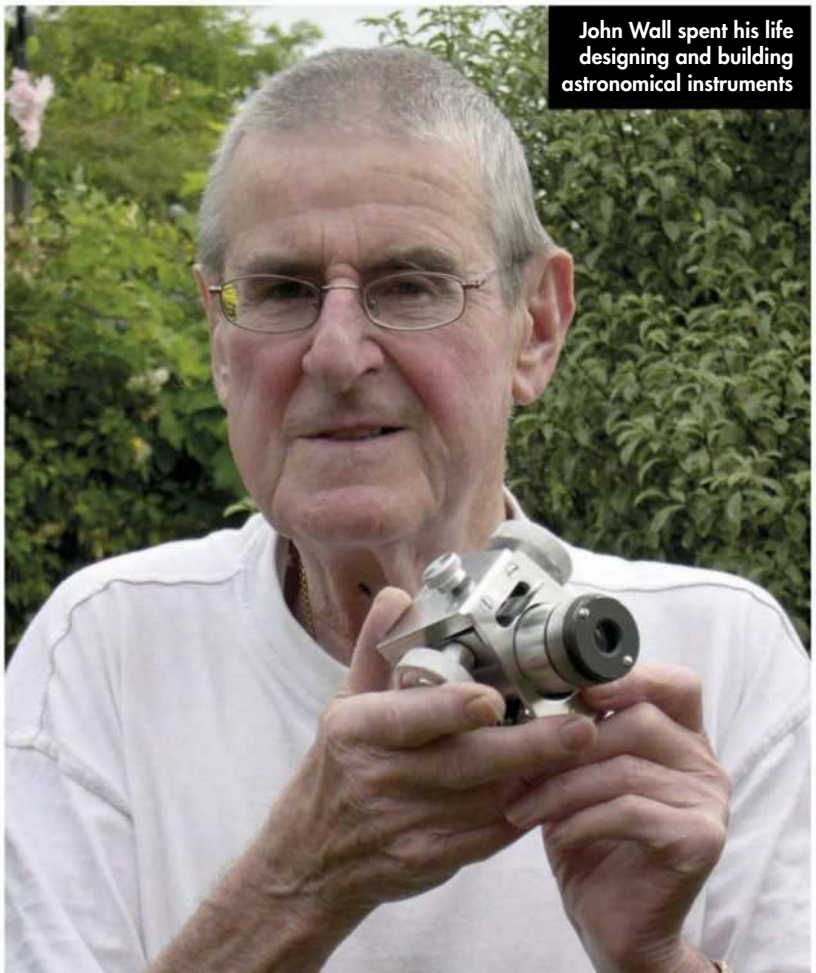
John interrupted his apprenticeship to do his national service. But during his army training, he took a trip to the Festival of Britain where he saw a 12-inch Newtonian and his imagination "caught fire". There and then, he decided to devote his life to building telescopes.

### First scopes, then the focuser

He'd previously tried building refractor scopes with his friend Dick Coker using lenses from spectacles (the pair had also made electrostatic generators and small bombs), but his efforts hadn't yielded much enthusiasm for observational astronomy. That changed during his national service tour in Malaya (now Malaysia), where he would watch the stars while on guard duty at night.

He left the army to resume his apprenticeship in 1953 and started grinding his first 6-inch mirror shortly after. He ground and figured the mirror, and built the tube from aluminium sheet scavenged on rubbish dumps around Dartford. After completing that telescope he purchased the crown and flint blanks to make a 6-inch refractor – this was a more

**ABOUT THE WRITER**
Instrument technician and amateur telescope maker Martin Dawson was a long-time friend of John Wall



John Wall spent his life designing and building astronomical instruments

TAMASFLEX/JOHN WALL X 2, MARTIN DAWSON

▲ **Optical testing of the instruments John built in his home workshop often took place in his bedroom**


► **The first Crayford Focuser John made is kept on display at the Crayford Manor House Astronomical Society**

complicated project and it took him a year to figure the lens.

Around this time he began an evening course in astronomy being taught by Dr Hugh Percy Wilkins, the noted selenographer, at the Crayford Manor House Adult Education College. Dr Wilkins was impressed when John told him about the refractor he'd built and the two of them discussed the possibility of constructing a Newtonian telescope for the college.

Using a £250 grant, John purchased a 12-inch disc of borosilicate glass, which he used to make the scope's mirror, then built the scope around the mirror using aluminium from an old delivery van. He also used the axles from a car to make the scope's polar and declination axes. The finished telescope got the attention of *Sky & Telescope Magazine,* which ran a story on it.

By now, John's managers at Vickers had recognised his flair for problem solving and promoted him to junior draughtsman, before making him a fully-fledged designer within the space of two years. But he still found time to work on his own scopes.

It was while making a 13.5-inch f/4 sky sweeper that John realised he needed a rack and pinion focuser. He thought those on the market were poor but one September afternoon in 1968 inspiration struck: why not mount the eyepiece on four rollers and press a smooth focusing pinion between the top two? The design meant that the focuser could only move in two directions and wouldn't wobble or stick.

Better still, he could make the pinion's support bracket hinged to release the focuser so that it could be easily swapped in the dark. Designs were drawn up and John started to construct a prototype. In two days it was finished.

When John demonstrated his focuser to the Crayford Manor House Astronomical Society the secretary suggested that he write about it for the *Journal of the British Astronomical Association.* His article caused a sensation and many people set about making and naming similar devices. But John had christened the original the Crayford Focuser after the place where he was born and his local astronomical society, and the name stuck.

"John thought that the focusers on the market were poor but one September afternoon in 1968 inspiration struck"

## Back to school

At the age of 39 John took redundancy from Vickers and began work as a lab technician at the grammar school his father had attended. While there he built a 24-inch Cassegrain equatorial telescope that became the Crayford Manor House Astronomical Society's flagship instrument.

John left the grammar school after seven years and joined the National Maritime Museum at Greenwich as a visual aids officer and optical engineer to the Royal Observatory. He remained with the National Maritime Museum for almost a decade before taking early retirement at 55. Free from the need to work for a living, John settled into telescope making full time.

During the 1990s his experiments with retrofocally corrected dialytes encouraged him to realise a life ambition and make a very large refracting telescope. John started building a 32-inch refractor in the late 1990s. He ground the objective lens and tested the optical system by looking through his bedroom window at objects 16km away. Once it was finished, he offered the telescope to the Hanwell Community Observatory near Oxford, where it remains to this day.

After 60 years in Dartford, John and his companion, Dr Joyce Porritt, a zoologist, moved to Coventry. There he befriended Peter Wise, a professional telescope maker who had seen the scope John had made for the Hanwell Community Observatory and wanted to use it as the basis for a commercial product. John helped Peter with the design then left him to develop the finished product, and thus the Zerochromat was born.

So culminated the telescope career of John Wall. From then on John worked on developing exotic refractor concepts and later discovered the Hypochromatic refractor.

John died on 27 January 2018, leaving behind his friend and companion Joyce.

# Looking for GOD?

## The Vatican and astronomy

The Catholic Church runs two private observatories and a staff of Jesuit scientists. **Terena Bell** went to meet them to find out more about their research projects



**ABOUT THE WRITER**
Terena Bell is a technology, health and science writer based in the US who's contributed to *The Washington Post*

The current Vatican Observatory moved to Castel Gandolfo in 1935. You can see its two domes at the far end

"We don't live by bread alone." That's one reason Brother Guy Consolmagno, director of the Vatican Observatory, gives for why the Catholic Church funds astronomy research. "We're human beings," he says. "We need to feed our souls, we need to feed our curiosity, we need to feed our love for beauty... our sense of worship." This worship is not separate from science, but linked: "You can be a scientist and be religious," he explains. "There isn't a conflict."

Georges Lemaître, the priest who developed the Big Bang theory, would have agreed. Lemaître's writings, Consolmagno says, state, "that God creates out of nothing and nothing is more than just a vacuum. Even a vacuum has space and time. And God creates that space and time. If God creates outside of time, then creation is not something that happened 13.8 billion years ago; it's something that's also happening right now." Just as a chair only has meaning because someone sits in it, Consolmagno says only God "can give meaning to the Universe, by being outside the Universe".

So as this Universe changes, Consolmagno and other Jesuit astronomers seek to understand it. The Catholic Church has a team of eight astronomers at two observatories, studying everything from Martian meteorites to quantum theory to near-Earth asteroids. Nearly half of their projects focus on stars: Chris Corbally studies peculiar stars, Richard D'Souza researches the outer light of galaxies and David Brown models subdwarf B stars.

"Something odd is happening in the atmospheres of Lambda Boötis-type stars," says Corbally. "Their peculiarity lies in having a solar-like proportion of carbon, oxygen, nitrogen and sulphur in their atmospheres, while elements such as iron, magnesium, aluminium and other 'iron-peak elements' are 10 to 100 times less abundant than would be expected." It's an anomaly that scientists have been trying to understand since 1943.

## Going deeper in

Lambda Boötis-type stars behave normally in volatile elements but are weak in refractory ones. Using asteroseismology, a technique that interprets frequency spectra to determine a star's internal structure, Corbally's research is looking into whether this is true throughout the entire star or just an exterior phenomenon. He reveals that he also, "just incorporated the very first release of distances from the Gaia space observatory to refine the evolutionary status of Lambda Boötis stars."

Richard D'Souza wants to know how galaxies grow. Not Big Bang, expansion-like growth, however; D'Souza is analysing galaxies' outer light to determine how accretion and the combination of smaller galaxies enlarge the Universe. Because of ▸

▲ Father Giuseppe Lais (1845-1921) at the Carte du Ciel Telescope during its time in the Vatican's Leonine Tower

▲ Pope Pius X appointed Father Johann Georg Hagen (1847-1930) as head of the Vatican Observatory in 1906

AGE FOTOSTOCK/ALAMY STOCK PHOTO, VATICAN OBSERVATORY X 2

Brother Guy Consolmagno at the eyepiece of the Carte du Ciel Telescope

VATICAN OBSERVATORY X-5, SCIENCE PHOTO LIBRARY

"We need to feed our souls, we need to feed our curiosity, we need to feed our love of beauty... our sense of worship. You can be a scientist and be religious. There isn't a conflict" - Brother Guy Consolmagno

▸ the low density of stars in the outer regions of galaxies, he explains, accretion histories are encoded deep within stellar structures. Low surface brightness makes this information difficult to uncover, so D'Souza has stacked approximately 5,000 images from galaxies with similar characteristics. This, he says, helps him, "study the average outer light of galaxies as a function of various galaxy properties [and] detect all that faint light in the outer part of the galaxy, which is generally not visible in a single image." As a result, D'Souza has proven how outer light increases as a function of a galactic stellar mass and shape.

## Shedding new (faint) light

D'Souza says this research has fixed a problem in commonly-used Galaxy Stellar Mass Function (GSMF) measurements.

"The extra light we detect in the outer part of the galaxy from the deep image stacks is generally unaccounted for in a normal, photometric, all-sky survey," D'Souza explains. "By previously failing to measure the outer light of galaxies, the estimates of the GSMF are generally biased." Corrections will be applied to "the already-measured stellar mass of galaxies in the Universe and thus provide a revised estimate of the GSMF."

Meanwhile, David Brown is studying small, hot stellar objects. He believes these subdwarf B stars give us a glimpse at the kind of star the Sun could become in five billion years. "Unlike young stars

# A short history of Catholic scientists

**Throughout the ages there have been many of religious conviction who have mixed science with faith**

Roger Bacon, the 13th century empiricist who laid the groundwork for the science of chemistry, was not an astronomer but he was a monk. So were Albert the Great, another well-known natural scientist of the 13th century, and Gregor Mendel (1822-1884), father of modern genetics.

▲ **George Lemaître believed the Big Bang helped prove God's existence**

Isaac Newton (1643-1727) was the father of classical mechanics – and two nuns. The first astronomer to classify stars with spectroscopy, Angelo Secchi (1818-1878), was a priest. Big Bang theorist Georges Lemaître (1894-1966) was a Catholic monsignor. In the world of science, Brother Guy Consolmagno points out, "There's no shortage of devout Catholics."

Consolmagno is director of the Vatican Observatory, founded by Pope Leo I in 1891, a time when, he says, "people were beginning to buy into the idea that maybe church and science were opposed."

But Catholic scientists have long contended they aren't. Lemaître, whose theory is often heralded as proof against God, instead wrote that the Big Bang *proves* God: an ever-expanding Universe is evidence of infinity, and infinite paradise is what Christ promised those who follow. "We may speak of [this Big Bang] as of a beginning. I do not say a creation," he wrote shortly after World War II. "The question if it was really a beginning or rather a creation – something starting from nothing – is a philosophical question which cannot be settled by physical or astronomical considerations."

# The Pope's scopes

**The Catholic Church's scientific instruments comprise historic refractors, reflectors and cutting edge instruments**

Contrary to popular belief, the Catholic Church does not own a telescope called LUCIFER. However, there is one called that at the Vatican Observatory's American outpost in Arizona, which is part of a shared facility used by various organisations. It was built by the Max Planck Institute for Extraterrestrial Physics, and the Vatican astronomers there do have access to it. With two 8.4m mirrors on a single mount, this large binocular telescope (LBT) has a light-gathering power equivalent to a single 11.8m instrument, but its binocular setup gives it the same resolving power as a 22.8m instrument. The telescope has been at the observatory since 2002, but was renamed LUCI in 2012.

The Church can trace its observational roots back to the late 16th century, when astronomical research helped to reform the Julian calendar. From the mid-19th century, the Papacy supported astronomical research with several observatories in Rome, but by the 20th century the Eternal City's lights had begun to impact the view. So in 1935 the observatory was moved 30km from Rome to the Pope's official summer residence, Castel Gandolfo. Its rooftop domes now house the Zeiss Visual Refractor Telescope, the Zeiss Double Astrograph, the Carte du Ciel Telescope and the Schmidt Telescope.

Inaugurated in 1957, the Schmidt is the newest and is joined to the same dome as the Carte du Ciel, a double refractor originally installed in the Vatican and moved to Castel Gandolfo in 1942. The Schmidt has a usable field six times larger – around 5x5 square degrees – and its 98cm spherical primary mirror has a 65cm corrector plate at its centre, which serves as its aperture. This 2.4m focal length instrument is capable of taking 20x20cm photographic plates and can also carry out spectroscopy.

▲ L-R, the Zeiss Visual Refractor, the Zeiss Double Astrograph, the Carte du Ciel Telescope and newest addition the Schmidt Telescope

▲ US-born Jesuit Father David Brown believes his research into subdwarf B stars will help shed light on stellar evolution

like the Sun, which generate and radiate energy from the fusion of hydrogen in their cores, subdwarf Bs derive their energy from the fusion of helium: a by-product of the previous fusion of hydrogen."

These stars are also five times hotter than the Sun, with a lifespan 1,000 times shorter. While many theories exist about how they're formed, no one knows for sure. One idea, Brown explains, is that subdwarf B stars, "form in binary systems – two stars revolving around one another, where the progenitor transfers most of its outer envelope to the companion star close to the point when it ignites its helium core. The result is a hot [subdwarf B] star orbiting around a companion star, the orbital period depending on how the two stars interact."

So Brown is developing a stellar evolution computer program that models subdwarf B evolution. Once complete, the tech will also perform asteroseismology, the same approach Corbally uses. Additionally, the priest is working on hypotheses that explain why only five per cent of clustered subdwarf Bs are in binaries compared to two-thirds of non-clustered stars.

In all Observatory work – stellar or not – Brother Consolmagno stresses the importance of, "being, able to praise the Creator by studying creation and studying it honestly," explaining that astronomy is a way, "to come to know the Creator by seeing the things He has created."

For the Church, science is a means with faith as its end. While this may not be how astronomers of different or no faith approach their research, the Vatican's results can still add value. After all, a better understanding of the Universe is what all astronomers seek.

# SKILLS



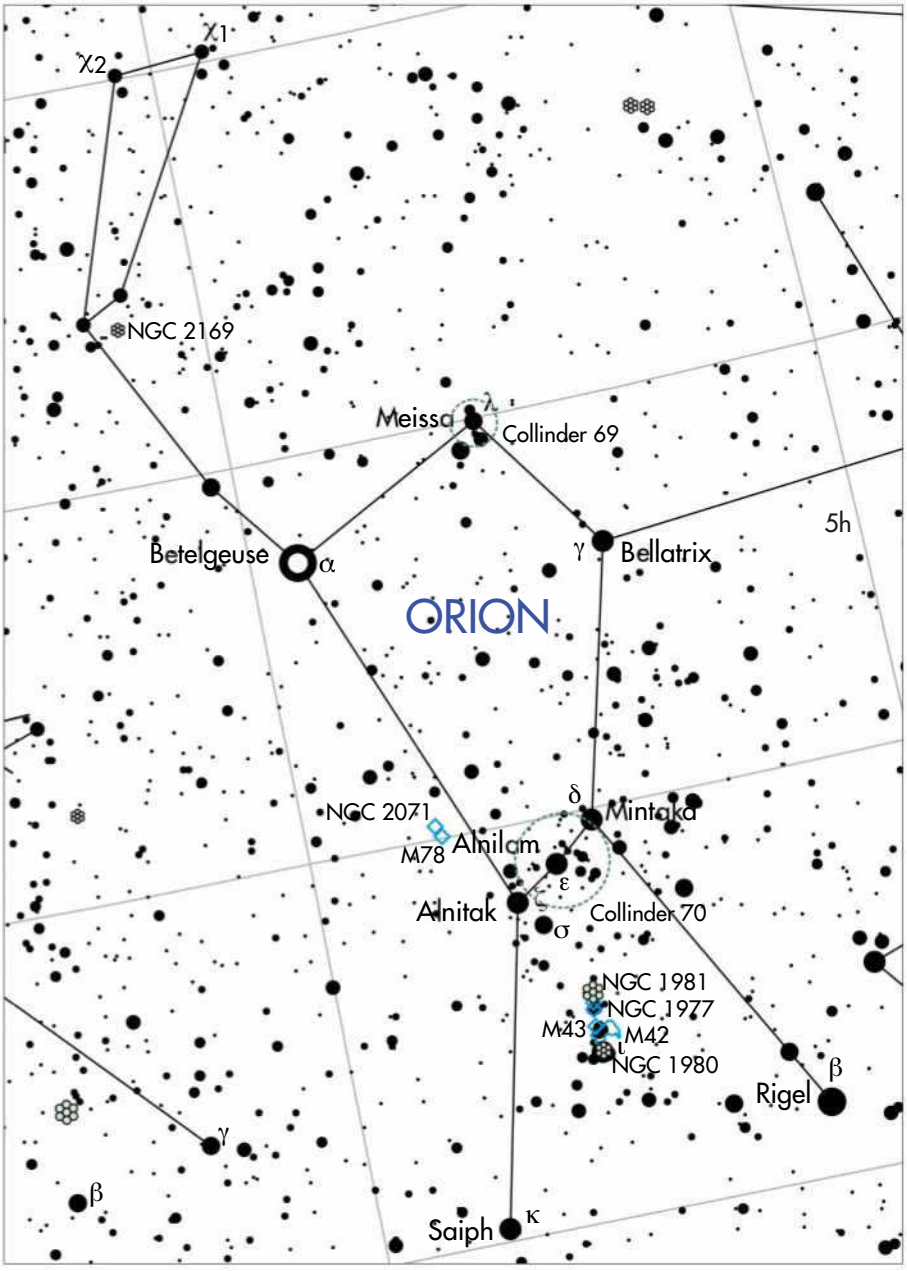
Brush up on your astronomy prowess with our team of experts

# The Guide

With **Stephen Tonkin**

## Star catalogues: which one to use and when

**Same stars, different designations – what catalogue is right for your observations?**




PETE LAWRENCE, TWO MICRON ALL-SKY SURVEY

▲ Bayer, Messier and New General Catalogue designations are used in *BBC Sky at Night Magazine*

When you click on a star to identify it in a good planetarium program, you may find you're offered a bewildering array of designations. For example, in the popular Stellarium software, Regulus is designated as "α Leo – 32 Leo – HIP 49669 – SAO 98967 – HD 87901 – HR3982 – WDS J10084+1158AB". Each of these designations comes from a different star catalogue, all of which have their own way of labelling stars. And that list merely skims the surface – if you use a program such as Guide v9.1 to search for double stars, it has over 100 catalogues to choose from. So why do you need all these?

The short answer is that you don't. Casual observers may well be satisfied by using only two designations: Bayer and Flamsteed (even so, many of us would be more likely to say "that blue mag. +5.0 star just above that bright one there" rather than "55 Cygni"). But as you grow in skill you may want to venture into more specialised areas, such as variable or double-star astronomy. You'll find that some catalogues are better suited to these specialised tasks than others and it's these we shall look at here.

### New and improved

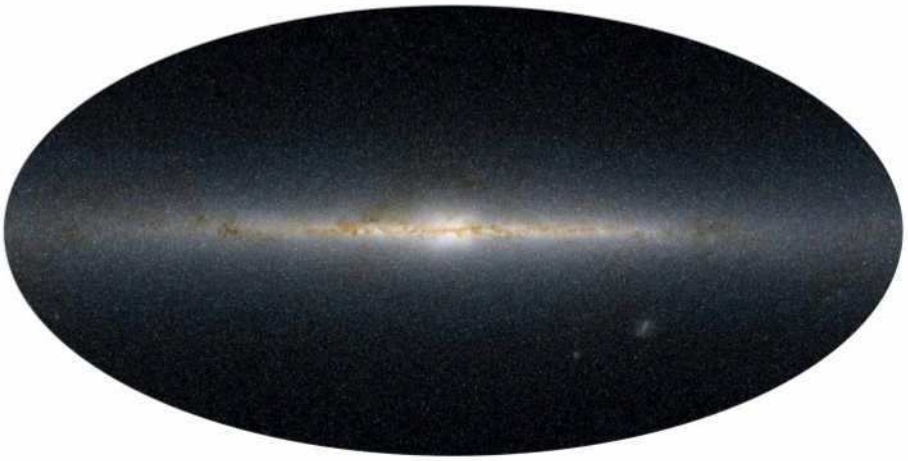
Though newer catalogues may be more accurate – they're made with improved techniques – some of the older catalogues can still be used effectively. One such example is the Henry Draper Catalogue (HD), published in 1924 by Annie Jump Cannon (and named for Henry Draper, whose widow financed it). Although more

recent data may be available in the Hipparcos (HIP) and Tycho-2 (TYC) catalogues, made using data acquired with the European Space Agency's Hipparcos satellite, the HD is still the best single source for magnitudes and spectral type of stars. Many newer star catalogues use data derived from the HD.

There are three catalogues that variable star observers will find useful. HIP and TYC are the most accurate and list every star to mag. +7.3, plus 95 per cent of those up to mag. +11.5. But Hipparcos only gathered data for three years, so these are inadequate for irregular and long-period variables. For these, and any other variables not in HIP or TYC, you should use the older General Catalogue of Variable Stars (GCVS), but be aware that it only gives rough coordinates and some of it is based on unreliable historical data.

## Selective information

Double star observers are well catered for by the Washington Double Star (WDS) and Sixth Orbit Catalogs, both of which are updated regularly (nightly, in the case of the WDS). As a minimum, WDS data includes positions, separations, magnitudes, position angles and the apparent motion across the sky for each star. If the orbit of a double star has been determined, the Sixth Orbit Catalog will provide orbital details and positional information for five years.



▲ **The Two Micron All Sky Survey (2MASS) measured the brightness of almost half a billion stars located in and around the Milky Way**

There are some astronomical observations for which only a subset of stars is relevant, such as when you're observing lunar occultations, where the Moon passes in front of a star and blocks its light. The Moon can only occult stars that lie within 6° 40' of the ecliptic, so it would be pointless to include any outside this band. Dedicated occultation prediction software, such as Occult v4.5, uses the XZ catalog, which is a corrected amalgamation of the original Zodiacal Catalog (ZC) with relevant data from the Smithsonian Astrophysical Observatory Star catalog (SAO) and AGK3 catalogue.

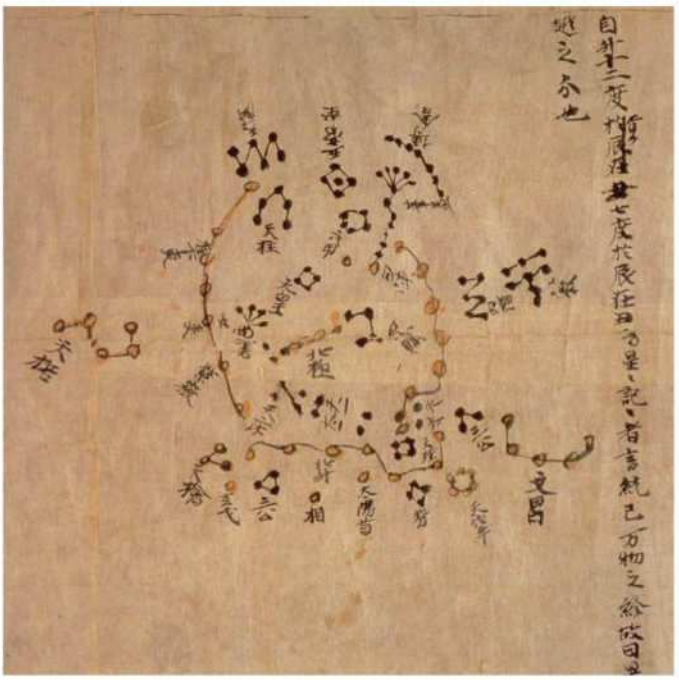
If you're an amateur theoretical astronomer, there are some other catalogues you might find useful. If your interest is infrared astronomy, for instance, the Two Micron All Sky Survey (2MASS) catalogued 470 million point sources (mainly stars) and 1.6 million extended sources (galaxies and nebulae), enough to keep you data-mining for a lifetime. In short, there's a tremendous amount of astronomical data available to you so, whatever your interest, you should be able to find a suitable catalogue.

STEPHEN TONKIN is *BBC Sky at Night Magazine*'s binocular astronomy expert

# Star catalogues through the ages

The earliest known star catalogues are from 1500 BCE Sumerian and Chinese cultures, but they do little more than record the names of stars. It wasn't until 370 BCE, when Greek astronomer Eudoxus of Cnidus wrote his *Phaenomena*, that there was a full catalogue of classical constellations visible from the latitude of the Mediterranean. In the second century CE, Ptolemy of Alexandria catalogued just over 1,000 stars in the *Almagest*, and this remained the standard work in Europe and the Near East for nearly a thousand years. Its star positions were corrected and updated in the Persian astronomer Ulugh Beg's *Zij-i-Sultani* in the 15th century, but it was the dominant catalogue until 1598, when Tycho Brahe produced a catalogue of 1,000 stars with extremely accurate positions.

Five years later, Johann Bayer published *Uranometria*, in which stars were identified by a Greek letter and the genitive of the constellation in which they lie (for example, Spica is Alpha (α) Virginis). The Greek alphabet contains only 24 letters, so he introduced Roman letters as well. The legacy of this lives on in Friedrich Argelander's system for designating variable stars, eg, RU Lupi. Bayer's system was limited and unsatisfactory, so the first Astronomer Royal, John Flamsteed, modified it by numbering the stars in order of Right Ascension and appending the constellation genitive, hence Spica is also known as 67 Virginis.



▲ **The Dunhuang star map dates to the Tang Dynasty (618–907 CE), and is currently the world's oldest preserved star atlas**

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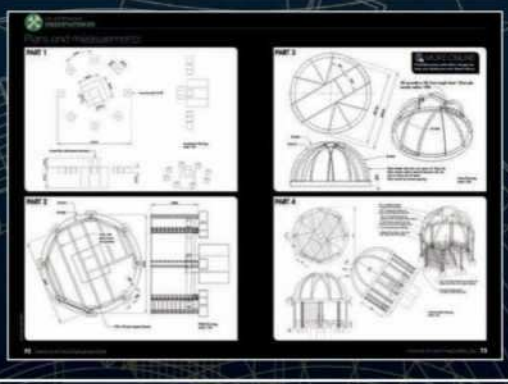


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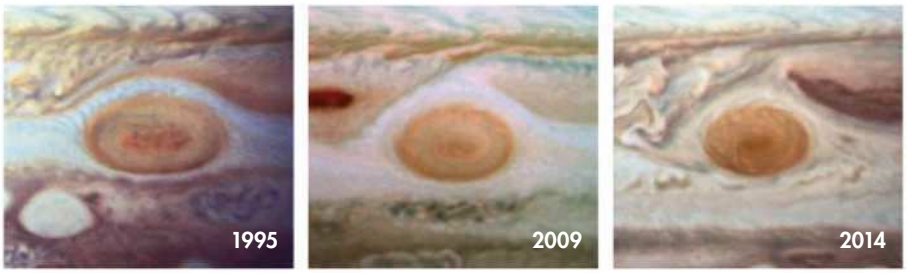
With
**Paul Abel**

# How to...

## Measure the Great Red Spot

Gauge the size of Jupiter's most famous giant raging storm


▲ **Hubble shows the Great Red Spot changing from 21,000km diameter (1995) to 18,000km (2009) and just 16,000km (2014). Now you can make your own measurements of the centuries-old storm**

NASA/ESA AND A. SIMON (GODDARD SPACE FLIGHT CENTER), PAUL ABEL

The giant planet Jupiter is once again prominent in the night sky. The planet is a popular target for amateurs as even a modest telescope will show its colourful bands and four bright Galilean satellites.

You can do more than just watch colourful cloud tops come and go, though. Jupiter's atmosphere is populated by all manner of interesting storms and features that you could spend a lifetime studying. But on this occasion we're confining our attention to one storm in particular – the Great Red Spot, a vast hurricane that has existed for centuries – and we're going to show you how you can measure its size.

### Hot and stormy

Jupiter is a gas giant and, unlike Earth, has no solid surface. A telescopic view reveals a planet crossed by dark belts and brighter zones. In reality, this is the top of a very extensive and tumultuous atmosphere – wind speeds of 100m/s have been recorded.

It's thought that the cloud deck is composed of three layers: ammonia clouds at the top, an ammonia hydro-sulphide layer beneath that and a dense layer of water clouds at the bottom. Beneath this cloud deck is a vast region of molecular hydrogen and helium. Even further down, the pressures and temperatures become so great that the molecular hydrogen and helium is squashed into a churning sea of metallic hydrogen and helium. This strange, metallic ocean at Jupiter's heart helps to generate the planet's enormous magnetic field.

Jupiter gives out much more heat than it receives from the Sun and this difference in heat drives the powerful weather systems on the planet. Since we can't see beneath the clouds, much of our understanding of Jupiter is the result of long-term studies of its atmosphere. The ▸

### TOOLS AND MATERIALS

**SOFTWARE**
WINJUPOS (to convert your transit times into System II longitudes).

**EQUIPMENT**
Telescope with an aperture of at least 6 inches, a logbook, a selection of medium- to high-power eyepieces (at least 200x to make the transit timings), a yellow filter (Wratten 15) and a blue filter.

▸ British Astronomical Association began these investigations in 1890, deriving many useful facts about the planet from amateur observations. Today, many professional astronomers are attempting to model the planet's dynamic atmosphere and amateur observations are of help here. Such studies are crucial if we are to understand how gas giants form and evolve.

The belts and zones of Jupiter's upper atmosphere are home to a variety of storms. Some are short lived, others can last for centuries. The Great Red Spot is the largest and most enduring. It can always be found in the Southern Equatorial Belt and although it may occasionally fade, it never truly disappears. There's some debate as to how old the spot is. Certainly the current spot has been observed since 1879, and perhaps even earlier; it's not clear if the spot reported by observers of the 1600s is actually the same one as we're observing today.

Observations from the late 20th century show that the Great Red Spot has changed: it used to be much larger and redder than it is now. And it has been slowly shrinking over time. Sometimes the shrinkage seems to accelerate while at others it's fairly constant; the reasons remain a mystery. The long-term forecast for the Great Red Spot is unclear: will it continue to shrink until it vanishes or start to expand again?

## The shrinking spot

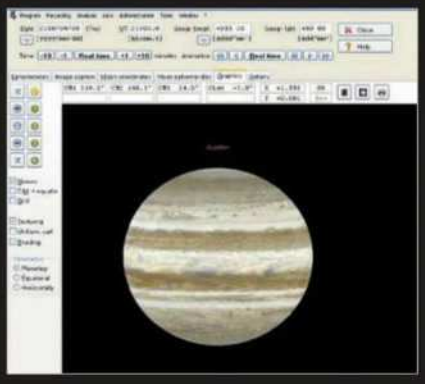
Measuring the shrink rate of the Great Red Spot is a straightforward task. It doesn't require any particular skill other than timing when the edges of the Spot lie on the Central Meridian. Using the free software WINJUPOS (http://jupos.org/gh/download.htm), you can then work out how large the Spot is in degrees and convert this into a size. Although you can see the Spot in a 4-inch telescope, a 6-inch telescope will probably be required for his project as you'll need a magnification of 200x or more.

This project requires a little planning as you'll need to work out when the Great Red Spot is visible. You should aim to measure it as often as possible and from these measurements you'll be able to tell if the Spot is shrinking or remaining constant. With Jupiter returning to the evening skies, now is the time to start your own investigations into the dynamics of the Solar System's oldest hurricane!

PAUL ABEL is an astronomer, broadcaster and writer who is based at the University of Leicester

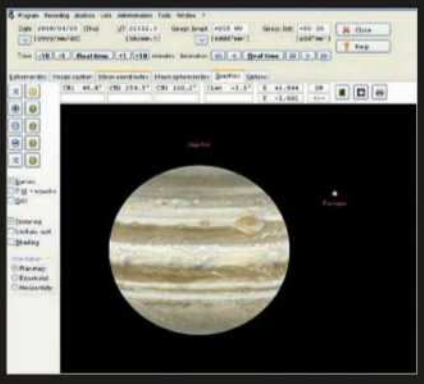
PAUL ABEL X 6

## STEP BY STEP



### STEP 1

**The first thing to do is plan when the Great Red Spot will be visible. In WINJUPOS, go to 'celestial bodies' in the menu and select Jupiter. Open the ephemerides in the 'tools' menu and find Jupiter, check the 'texture' box to display Jupiter's features.**

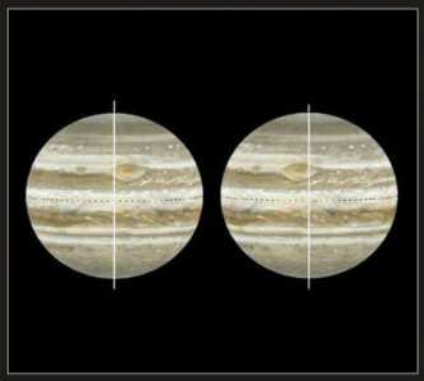


### STEP 2

**In the graphics tab, click the >> button until the Great Red Spot appears. You can then see when it's visible. If you want a telescopic image (with south at the top) go into the 'options' tab and click 'Sr – south at top' under 'image orientation'.**

### STEP 3

**Get out to your scope a good 20 minutes before you begin observing so your eyes adapt to the darkness. Spend about 15 minutes observing the Great Red Spot before it reaches the Central Meridian (CM). You can use a blue filter to enhance contrast.**

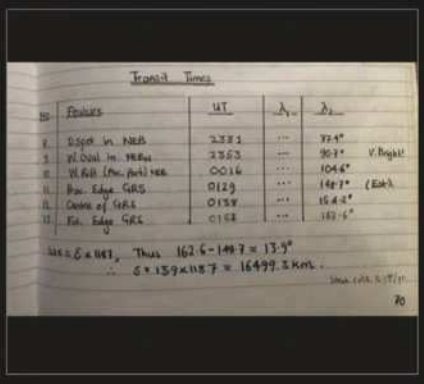


### STEP 4

**The Great Red Spot will drift towards the left (south up, no star diagonal). The left-hand or 'preceding' edge will touch the CM first. Record the time you think this occurs in your logbook. You'll then need to record the time when the following edge reaches the CM.**

### STEP 5

**Next, convert your times into longitude in WINJUPOS. Go to the 'ephemerides' tab, enter the date and time you recorded for the preceding and then proceeding edge. You'll see three values for longitude: the Great Red Spot is in System II, so use this value.**



### STEP 6

**Subtract the smaller value of longitude from the larger to get the width of the Great Red Spot in degrees (call this W). Finally, multiply W by 1,187km (approx 1° of Jupiter's circumference). Repeat this process often to see how the Spot's size changes over time.**

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# Image PROCESSING

With
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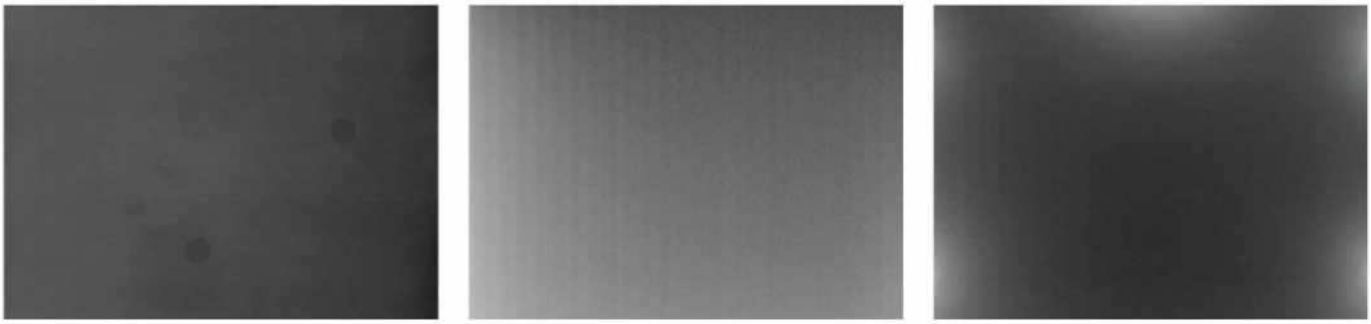
## Calibration frames

**Reduce the thermal noise in your astrophotos with the help of calibration frames**

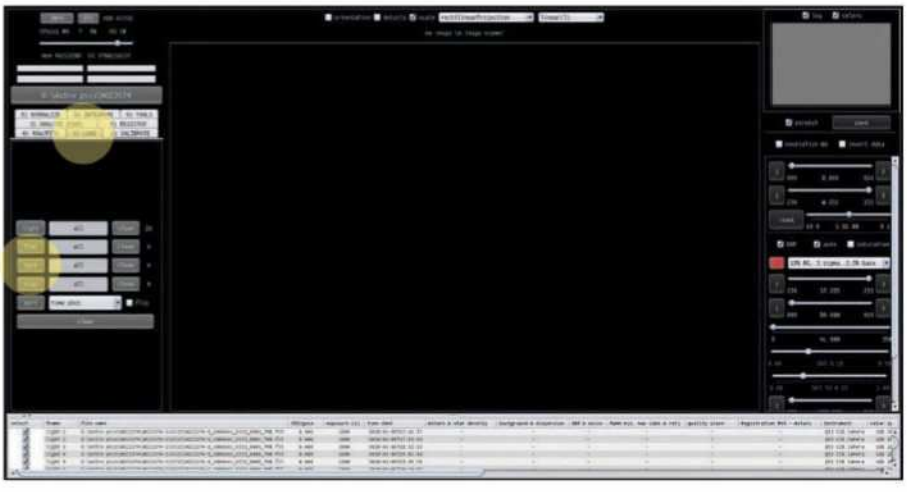


▲ The flat frame (left) shows dust; the master bias frame (centre) removes any light readings in the sensor; master dark frames (right) show hot pixels

Calibration frames should play a key role in your data processing. With Astro Pixel Processor software (APP) using calibration frames is easy and they make such a difference to the images you produce that you'd be mad not to use them.

The calibration frames we'll be using are flats, darks and biases. Bias frames remove the electronic signal inherent in the sensor and should be taken with the dust cap on and at the fastest exposure possible. Darks are taken with the dust cap on and at the same exposure length as the light frames (the shots of the object you're imaging); they're used to remove hot pixels and amp glow within the sensor. Flats are taken to counter inherent vignetting and any dust on the filters or optics. These aren't taken at a specific exposure length as the aim with flats is to capture data around a third to halfway across the histogram. As such, flats need to be taken against a light source, for example a light box.

It's worth noting that calibration frames benefit massively from being taken at the same temperature as the light frames. This can be almost impossible for DSLR users, but easy if you camera is astro-cooled.



ALL PICTURES: SARA WAGER

▲ Choose 'load' and then select whether you want to add your flat, dark and bias frames

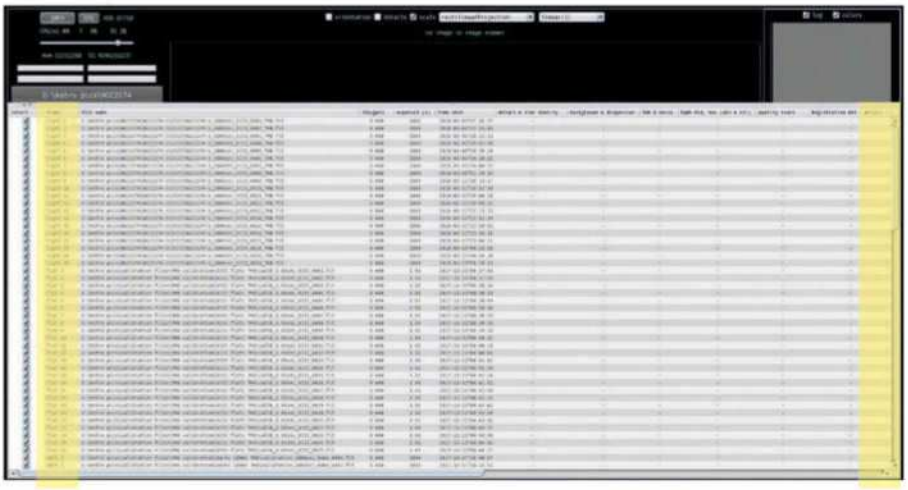
Calibration begins by creating a Bad Pixel Map (BPM) so you can deal with any hot and cold pixels. After that you're going to use the integration process to create master calibration frames. If nothing in the imaging train changes then your flat frames can be reused for subsequent imaging sessions; bias and dark calibration frames can be reused for many months. We used our calibration library for more than eight months.

### Get started

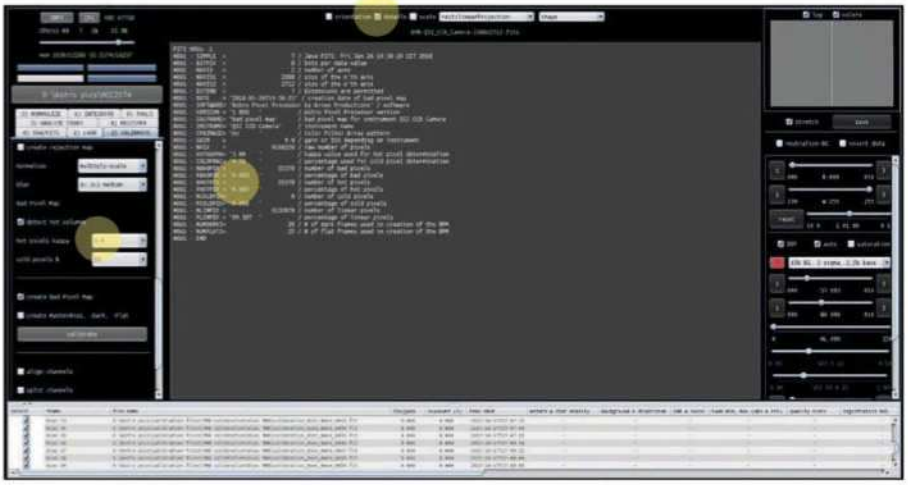
Start by opening APP and loading your light frames by selecting the 'Load' option from the menu on the left and 'light' from the frame options below the menu.

Add your flat, dark and bias frames by following the same process ('Load>flat'; 'Load>darks'; and 'Load>bias'). There are no limits for how many of these frames you can load – we like to add as many as possible, perhaps 30 flats, 30 darks and 100 bias frames. You can check that all your calibration frames have loaded by using the right scroll bar on the lower console.

Producing a BPM can take a bit of trial and error. Select the 'Calibration' option on the menu. Keep everything at its default setting but ensure that the 'create bad pixel map' and 'detect hot columns' tick boxes are ticked, and that the 'Create MasterBias, -dark -flat' tick box is not. Then click 'Calibrate' to create your BPM.



▲ Check all of your calibration frames have loaded by scrolling down through the lower console



▲ Click 'details' at the top of the screen to see your bad pixel map information

Double click the 'bad pixel map 1' file at the bottom of the lower console to see the BPM, then click the 'details' tick box at the top of the window to see the readings. What you want to see is about three per cent hot and cold pixels. Adjust the 'hot pixels kappa' rating using the drop-down menu on the calibration panel (lower the value to increase the percentage) and click 'Calibrate' again, then re-check your bad pixel map. Repeat this process until you reach about three per cent. We find that a Kappa figure of 1.9 works well.

## Make your master frames

To create reuseable master calibration frames there are a couple of steps that need to be followed at the start of your first integration process. Once the master frames have been created, you can load them up instead of all the individual frames on each subsequent integration.

Ensure that the 'Create MasterBias, -dark -flat' tick box is ticked and the 'create bad pixel map' and 'detect hot columns' are not, then click 'Save calibrated frames'. APP will create master calibration frames in the lower console. These will be saved automatically in your original working directory along with your calibrated lights. We like to save these calibrated lights so that they can be used and added to subsequent imaging runs.

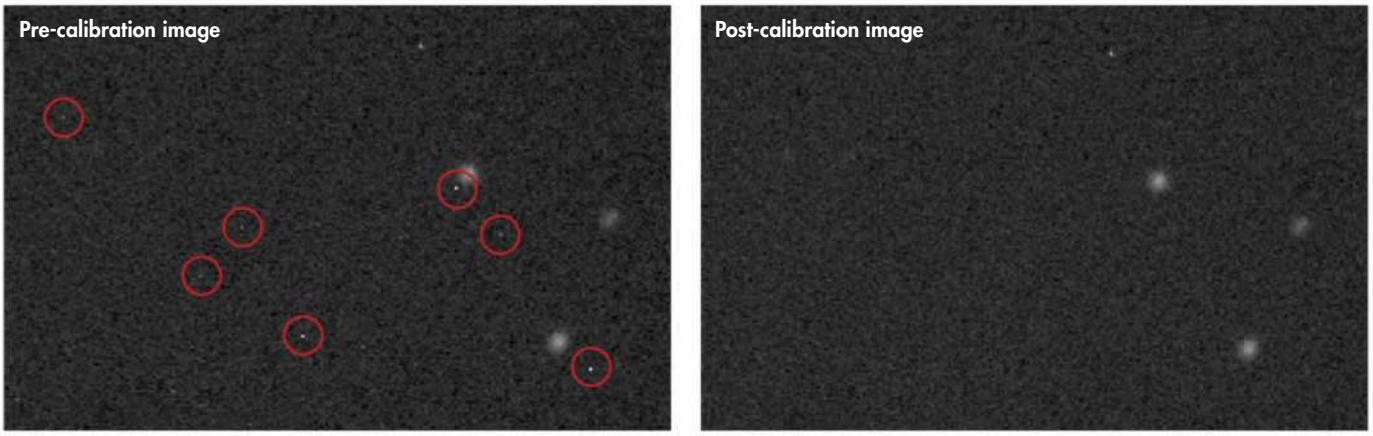
Add the bad pixel map you created earlier by going to 'Load>flats' and select your bad pixel map. This will load into the lower console along with your light, flat, dark and bias frame as well as your masters.

It's always worthwhile checking how well your calibration frames have worked. You can do this by opening a light frame in the lower console by double clicking it. The image will open in the middle screen. Along the top of this you'll find a drop-down 'image' menu. Click on this and select 'l-calibrated' and the image will change to the calibrated image. This is a useful visual check. You can zoom in by clicking the left button on your mouse to see if most of the hot pixels have gone.

From this point, everything can be left at default except 'Outlier rejection' in the 'Integration' tab. Select 'winsor sigma clip' and 'kappa 2.5'. This will ensure that any final hot pixels are eliminated. Click 'integrate' and APP will create a calibrated, integrated stack of your lights data, which can be viewed in the lower console.

Now when you next integrate any data you just need to load in the master dark, bias and flat frames, and the BPM, then integrate them as above.

SARA WAGER is an amateur astronomer who loves imaging nebulae in narrowband




▲ Hot pixels visible in the pre-calibration image (circled red) have been virtually eliminated in the post-calibration image

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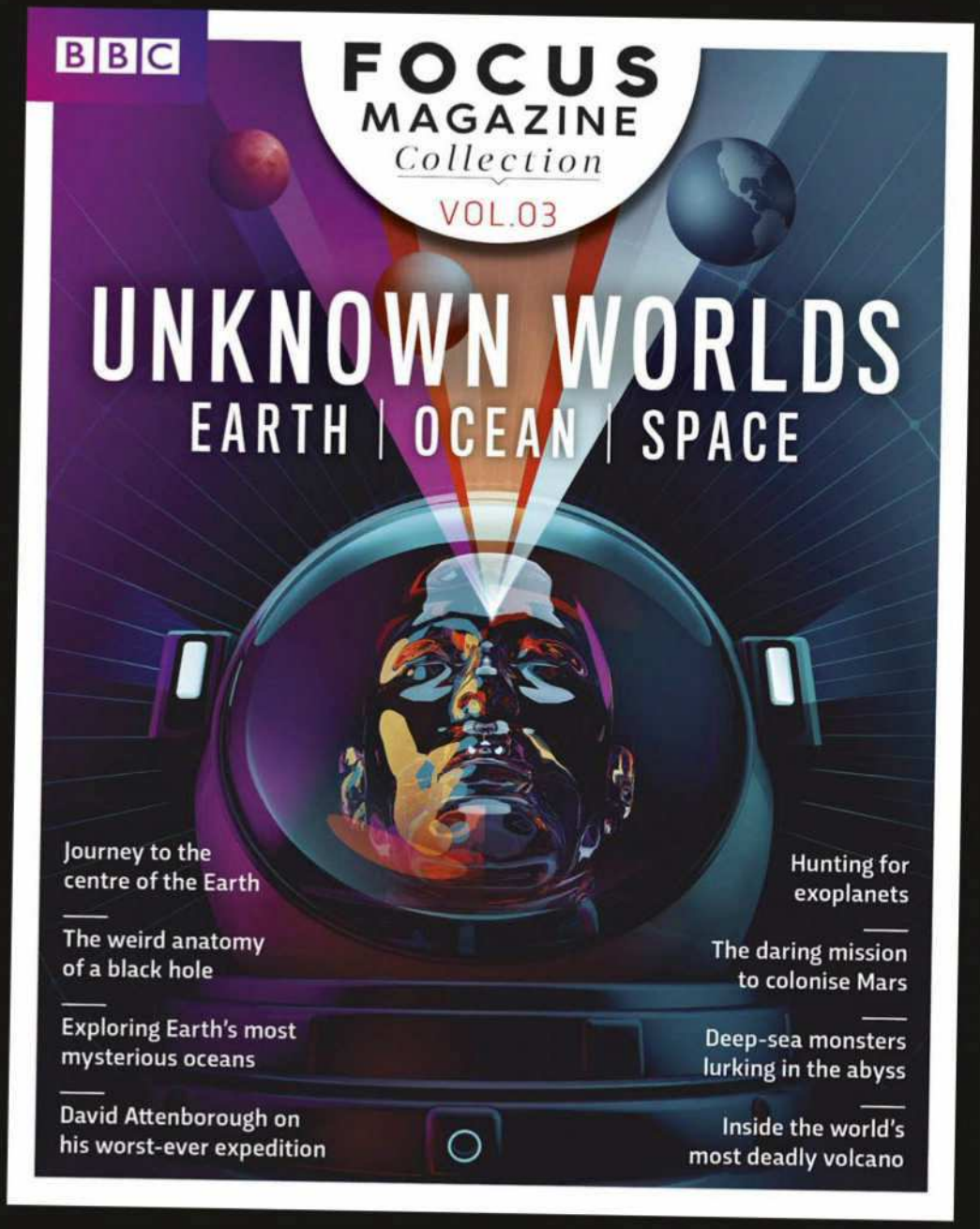


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# Scope DOCTOR

With **Steve Richards**

## Our equipment specialist cures your optical ailments and technical maladies

### *My Celestron NexStar 8SE has some silver spots on the inside of the lens. Should I remove the lens to clean them?*

KEVIN SMITH

The Celestron NexStar 8SE is a very popular 8-inch Schmidt-Cassegrain telescope (SCT) mounted on an altaz Go-To mount. Schmidt-Cassegrains are reflecting telescopes with a spherical primary mirror but they have a specially figured correcting plate on the front of the optical tube to remove the aberrations that such a mirror would normally produce, namely spherical aberration.

Unless you know that the silver spots are spoiling the views through the telescope, which is unlikely, or that the spots are in any way organic or corrosive, which means that they could cause problems in the future, the best plan is to leave well alone. Cleaning optics can lead to more problems than you solve as there is always the risk of micro-scratching the surfaces or worse.

However, if you do decide that the corrector plate must be cleaned then proceed carefully and methodically.

There is much debate over whether or not the corrector plate and primary mirror in a given telescope are matched at the factory but it makes sense to ensure that you can return the corrector plate to its original orientation. This can be done by removing the screws in the retaining ring and marking the edge of the corrector plate and the optical tube with an indelible marker before removal and subsequent cleaning.

However, a much safer approach is to return the telescope to the importer's repair centre and let them do the work for you.

PAUL WHITFIELD, STEVE MARSH

◂ **The Celestron NexStar 8SE, a favourite of amateur astronomers since the 1970s**

**A dew shield is one way to help combat condensation**

### *I have a Schmidt-Cassegrain scope. What's best for stopping lens condensation on colder nights?*

PAT TURNER

Schmidt-Cassegrain telescopes (SCTs) seem to act as 'dew magnets' because of their very exposed and relatively large front corrector plate. Unlike refractors which have a dew shield to help keep dew at bay, SCTs have no such protection as part of their appeal is their very short physical length and an in-built dew shield would increase overall length by quite a bit. A good starting point, therefore, is to add a dew shield. This can be made from a camping mat by wrapping a portion of the mat, cut to size, around the front of the telescope tube. But there are commercial versions available too and these make for an elegant solution to the problem.

However, that large chunk of glass may still require some additional assistance to stop dew forming on its surface and a dew heater with a controller and a battery pack would almost certainly resolve the issue for you.

## STEVE'S TOP TIP

***What are counterweights for?***

Telescope mounts allow the telescope to follow celestial objects as they traverse the sky. On an altaz mount, which moves horizontally and vertically, the weight of the telescope sits immediately above the mount. However, with an equatorial mount one of the axes – the right ascension axis – is tilted at an angle that matches your latitude. This change in orientation places the weight of the telescope off to one side of the right ascension axis. So to stop the telescope from rotating downwards under the effect of gravity, a counterweight placed on an extension bar is required to exactly balance the weight of the telescope tube.

Steve Richards is a keen astro imager and an astronomy equipment expert

**Email your queries to scopedoctor@skyatnightmagazine.com**

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Sky at Night MAGAZINE

# Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

## HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
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★★★☆☆ Average
★★☆☆☆ Poor/Avoid

## This month's reviews

### FIRST LIGHT







### BOOKS




### GEAR



Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**


**SEE INTERACTIVE 360° MODELS OF ALL OUR FIRST LIGHT REVIEWS AT WWW.SKYATNIGHTMAGAZINE.COM**

**90**

**We turn the Sky-Watcher StarGate-500P's big eye on the night sky**

# FIRST LIGHT

See an interactive 360° model of this scope at www.skyatnightmagazine.com/stargate_dob

# Sky-Watcher StarGate-500P SynScan Dobsonian

WORDS: PAUL MONEY

## Bigger appears to be better when it comes to telescopes

### VITAL STATS

- **Price** £5,499
- **Optics** 508mm (20-inch) primary mirror
- **Focal length** 2,000mm f/4
- **Mount** Dobsonian Go-To Altazimuth
- **Ports** Power connector, SynScan AZ hand controller
- **Database** 42,900+ objects
- **Tracking rates** sidereal, lunar, solar tracking and Freedom-Find Dual-Encoder system
- **Extras** 10mm (1.25-inch), 28mm (2-inch) eyepieces, 9x50 straight-through finderscope, fabric shroud
- **Weight** 90kg
- **Supplier** Optical Vision Ltd
- **www.**opticalvision.co.uk

**SKY SAYS...**
Objects took on stunning new life with the 500P – this is a great instrument to invest in

WWW.THESECRETSTUDIO.NET, PAUL MONEY X 2

John Dobson dreamed of owning a large telescope that could give him views similar to those in photographs of the deep sky; little did he know that he'd start a revolution in telescope making. Now Sky-Watcher has introduced its StarGate range of very large Dobsonian telescopes, consisting of the 450P (in two variants, basic and SynScan) and the 500P SynScan. When we were offered the chance to review the latter, we couldn't resist.

The StarGate 500P has a 508mm (20-inch) primary mirror with a focal length of 2,000mm to provide what's known as a 'fast' focal ratio of f/4. It comes with a 28mm, 2-inch (71x) and a 10mm, 1.25-inch (200x) eyepiece; a 9x50 straight-through finder; three 1kg counterweights; a light baffle and a fabric tube shroud. A SynScan AZ hand controller and power cable complete the system.

This is a half-metre class instrument and weighs 90kg when fully assembled – make no mistake, it's not for the faint hearted. Initial assembly does include some fiddly small attachments, but once they're in place they can be left alone. You should also bear in mind that although we managed to assemble it on our own (just about) in around 30 minutes, the task is far easier with two people.

Power is provided by an optional 12V powertank and, once powered up, we used the handset to input details such as location, time and date. We then had a choice of two alignment options: brightest star or two-star alignment. Although each time the alignment was accurate, we did have an initial problem with the subsequent Go-Tos, which were often out by several degrees in azimuth. With advice from Optical Vision, the suppliers, and Sky-Watcher, we were able to resolve the issue and subsequent Go-To sessions placed the targets in the inner 50 per cent of the view of the 28mm eyepiece.

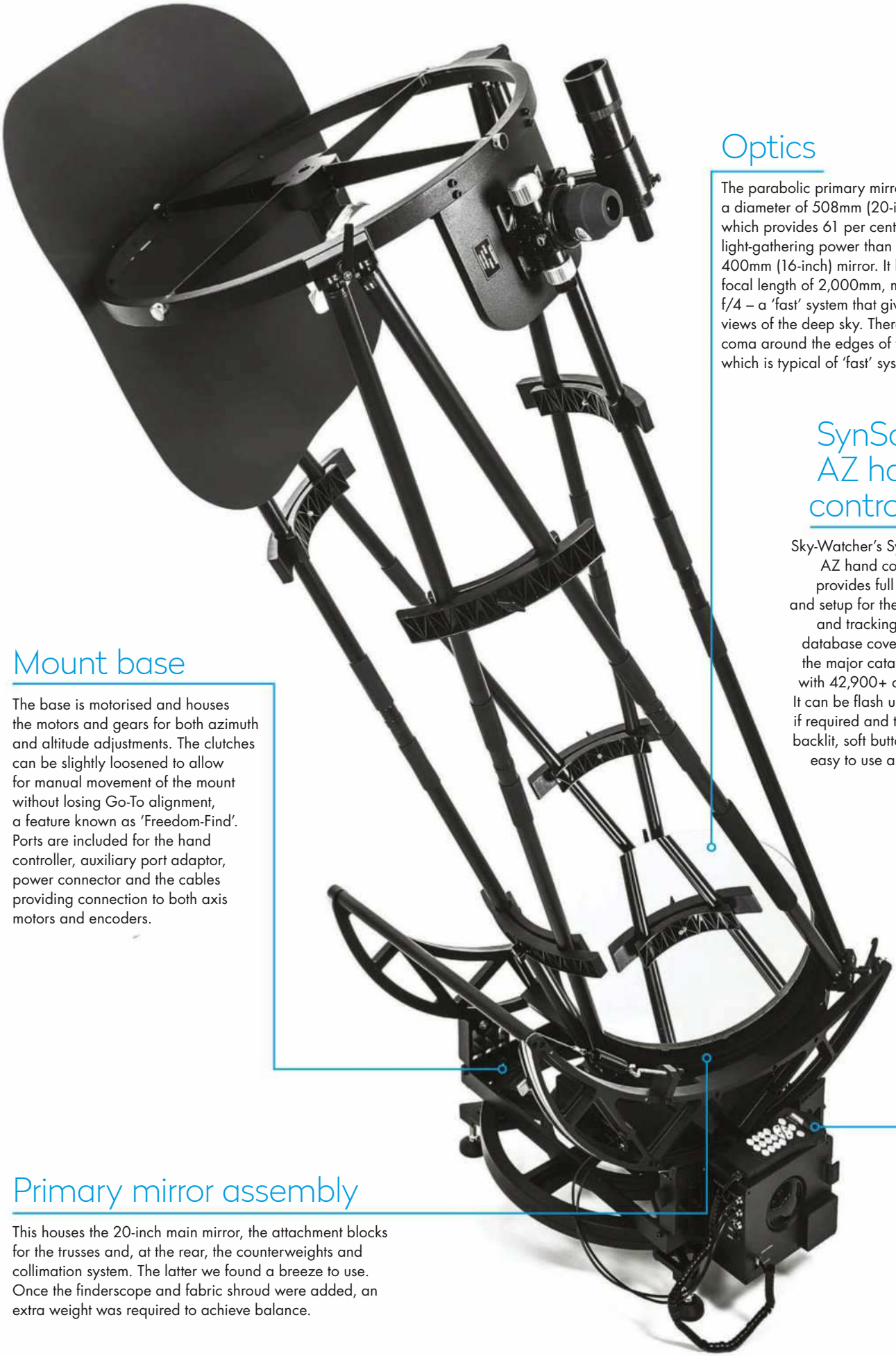
## Gasp-inducing views

We took a tour of some of the best deep-sky targets the sky has to offer and were wowed by the views. In twilight, the double star Albireo was stunning ▸

## A big light

For this review, we were kindly loaned an Ethos 21mm 100° eyepiece and a Parracor corrector by the Widescreen Centre. We found the 21mm and StarGate 500P an ideal combination. With it we examined a winter favourite, the Orion Nebula, and were bowled over with the amount of faint nebulosity and detail we could see – so much so that we coupled our Canon EOS 50D DSLR to see what we could capture. This is an altaz system and does not follow the stars in an equatorial mode, so exposures must be short to avoid field rotation. Even so, we captured many targets with just 10-second exposures, such as the Whirlpool Galaxy, M51, at ISO 2000, and the Orion Nebula at ISO 800. Changing to our GPCAM2 290C, we captured the heart of the Orion Nebula and trapezium stars with 1/3-second exposures and stacked 200 frames to give a very satisfying result. Overall, we had to conclude that this system is also a capable astrophotography instrument too.

▲ Top: The Orion Nebula taken with a Canon EOS 50D DSLR
Bottom: The Trapezium taken with a GPCAM2 290C



## Optics

The parabolic primary mirror has a diameter of 508mm (20-inch), which provides 61 per cent more light-gathering power than a 400mm (16-inch) mirror. It has a focal length of 2,000mm, making it f/4 – a 'fast' system that gives bright views of the deep sky. There's a little coma around the edges of the field, which is typical of 'fast' systems.

## SynScan AZ hand controller

Sky-Watcher's SynScan AZ hand controller provides full control and setup for the Go-To and tracking with a database covering all the major catalogues, with 42,900+ objects. It can be flash updated if required and the red-backlit, soft buttons are easy to use and see.

## Mount base

The base is motorised and houses the motors and gears for both azimuth and altitude adjustments. The clutches can be slightly loosened to allow for manual movement of the mount without losing Go-To alignment, a feature known as 'Freedom-Find'. Ports are included for the hand controller, auxiliary port adaptor, power connector and the cables providing connection to both axis motors and encoders.

## Primary mirror assembly

This houses the 20-inch main mirror, the attachment blocks for the trusses and, at the rear, the counterweights and collimation system. The latter we found a breeze to use. Once the finderscope and fabric shroud were added, an extra weight was required to achieve balance.

# FIRST LIGHT

◂ Cropped view of the Whirlpool Galaxy, M51, taken with a Canon EOS 50D DSLR, 8x10sec at ISO 2000, processed with APP

▸ in both eyepieces. Later, under dark skies, the M35 star cluster in Gemini filled the view of the 28mm and we noted coloured stars scattered throughout it. We picked up the normally fainter nearby cluster NGC 2158, which was bright and a mass of stars.

Objects that appeared as a smudge of light in smaller instruments took on new life with the 500P, such as M1, the Crab Nebula, which showed as a strongly mottled oval with undulating edges and clear views of the central stars.

Turning to galaxies, we couldn't help but gasp when we homed in on the Cigar Galaxy, M82, with the 10mm eyepiece and it displayed lots of the dust features we normally associate with photographs. Dropping down to the 28mm eyepiece, we could just fit its neighbour M81 in the view with a clear spiral nature to it. The Whirlpool Galaxy was replete with spiral structure and, as we continued our deep-sky tour, we could almost feel John Dobson beside us chuckling at our reaction to the views.

The Moon seemed like an odd target for such a 'light bucket', but was full of mesmerising detail. We homed in on Uranus and were rewarded with a lovely pale green ball instead of the usual view of a small disc. We even picked out its five moons, although Miranda, being so close to the disc, was still a challenge. Jupiter was spoiled by the low altitude and poor conditions in the early morning, yet the colours in its bands and the Great Red Spot were clearly visible.

Overall, the Stargate 500P is an impressive system; societies and clubs that have sufficient funds and want a real deep-sky light bucket with Go-To functionality will find that this is a great instrument to invest in. Just remember to keep a step ladder with it, as looking up towards the zenith puts the eyepiece more than 2m above the ground! S

**SKY SAYS...**
**Now add these:**

**1.** Sky-Watcher 17Ah rechargeable power tank

**2.** SynScan Wifi adaptor

**3.** Sky-Watcher GPS mouse

## Truss and secondary assembly

The easy-to-assemble truss struts attach to the primary mirror assembly first, and then the secondary cage is attached. The latter houses the Crayford-style, dual-speed focuser and the 9x50 finderscope. The light baffle stops stray light entering the focuser assembly, while a fabric shroud (also included) can be used to protect and darken the tube.

## Verdict

| | |
|---|---|
| **Assembly** | ★★★★☆ |
| **Build and design** | ★★★★★ |
| **Ease of use** | ★★★★☆ |
| **Features** | ★★★★☆ |
| **Optics** | ★★★★☆ |
| **OVERALL** | ★★★★★ |

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# FIRST LIGHT

See an interactive 360° model of this camera at **www.skyatnightmagazine.com/canon_m100**

# Canon EOS M100 camera

## Can Canon's stripped-down mirrorless handle astrophotography?

WORDS: PETE LAWRENCE

### VITAL STATS

- **Price** £449.99
- **Sensor** APS-C (CMOS) 22.3x14.9mm, 3.7 micron pixels arranged in a 6,000x4,000 array (24.2 megapixels)
- **Shutter range** 1/4,000th-30 seconds, bulb mode available
- **ISO range** 100-25,600
- **Memory cards** SD, SDHC, SDXC (UHS-I compatible)
- **Lens type** EF-M
- **Size** 108.2 x 67.1 x 35.1mm
- **Battery** 1 x Rechargeable Li-ion Battery LP-E12E
- **Weight** 302g (body only, includes battery and memory card)
- **Supplier** Canon UK
- **www.**canon.co.uk
- **Tel:** 01582 726522

**SKY SAYS...**
An easy-to-use camera for ultra-portable, deep sky photography but with some limitations

The EOS M100 is an entry-level, mirrorless, interchangeable lens camera (MILC) from Canon that provides through-the-lens subject monitoring directly via the sensor. It looks like a stripped-down DSLR, but has neither a flip mirror nor viewfinder optics, resulting in a more compact, lighter and easier-to-carry camera body. The lack of a flip mirror also eliminates possible camera shake at the start of a long exposure when the mirror moves out of the way.

Canon's M-series cameras are designed to use EF-M lenses, which are smaller and lighter than conventional Canon EF/EF-S lenses. But you can still use EF/EF-S lenses on the EOS M100 with the help of an optional, albeit pricey, adapter. The adaptor also allows you to connect the EOS M100 to a telescope via an EF-T mount adaptor.

You select the shooting mode using a menu system and can choose between aperture priority, shutter priority, programmable or manual modes. You can set the shutter speed to take exposures lasting anywhere between 1/4,000th of a second to 30 seconds, or even longer with the use of the bulb mode. ISO settings extend from 100-25,600, but we achieved excellent night-time results with mid-range values of 1,600-3,200.

The rear display serves as a touchscreen interface for control settings and image review. The display flips up by 180° around a top hinge, which is not only helpful for taking selfies but, more crucially, provides easier access to the screen with awkward telescope configurations. Sadly, there's no red-light option to preserve your eyes' dark adaptation.

## Control issues

One of our biggest issues with the EOS M100 is the lack of a direct connection port to control it remotely. Only USB and HDMI connections are provided. And as with other Canon's M-series cameras, the EOS M100 does not currently support tethered control via applications such as *BackyardEOS*.

However, remote operation can be achieved to a degree by connecting the camera via Wi-Fi, Bluetooth or near-field connection. We used the *Canon Camera Connect* app on a Samsung Galaxy S7 smartphone (Android) and were able to frame and review images as well as remotely control ▸

## Portable imaging

As an astrophotographic travelling companion, the EOS M100 is certainly flexible, easy to use and highly portable. Whether coupled to a standard lens or to a telescope, the EOS M100 is capable of taking some great astronomy shots. It outputs images in the Canon RAW file format and also HD video (1,920x1,080). Despite lacking the bulk and weight of a traditional DSLR camera, the EOS M100 still manages to emulate much of their functionality.

With a compact body measuring a mere 108.2x67.1x35.1mm and weighing in at just 302g, the EOS M100 is a fantastic camera for travelling and ideal for coupling to a small refracting telescope. All of which makes it perfect for taking on location for deep sky photography sessions.

The M-series EF-M lenses are also compact, lightweight and easy to carry. A remote shutter release is important for many astrophotographic sessions and as long as you have charge in a Wi-Fi, Bluetooth or near-field-connection-enabled device, it's possible to use them for remote operation. One key omission is the lack of a physical connection for an intervalometer.

◂ **The M100 and a small refractor are ideal for ultra-portable astrophotography**

WWW.THESECRETSTUDIO.NET X 5, PETE LAWRENCE


## EF-M compact lenses

The EOS M100's small profile is reflected in the design of the EF-M lenses, which the camera has been tailored to use. The lenses are smaller than the EF/EF-S lenses normally used with DSLR cameras. The camera is supplied with EF-M 15-45mm and 55-200mm lenses, giving good coverage for wide- and medium-field photography. EF/EF-S lenses/ T-rings can be attached using an optional EF-EOS M adapter, which costs £104.99.


## Clear controls

Unlike a traditional DSLR, the EOS M100's body is uncluttered with relatively few control buttons. One of the bugbears for astrophotography is trying to work out which unlit button to press in the dark, so the lack of confusion here is welcome. Instead, many of the commonly used settings, such as camera mode, are available through the camera's touchscreen menu system.

## Bluetooth & Wi-Fi control

The M100 offers remote control via Wi-Fi, Bluetooth or a near-field connection link. The Wi-Fi link allows the camera to connect with devices such as smartphones and tablets, with remote control being established via apps such as *Canon Camera Connect*.

## Sensor

The sensor at the heart of the EOS M100 is an APS-C format, 24.2 megapixel CMOS device. This is the same sensor used in the Canon EOS 80D DSLR. It consists of a 6,000x4,000 array of 3.7 micron pixels producing an imaging area that measures 22.3 x 14.9mm.

# FIRST LIGHT

**SKY SAYS...**
Now add these:

**1.** Spare rechargeable Li-ion battery LP-E12E

**2.** EF/EF-S lens adapter

**3.** Canon EF-M 55-200mm f/4.5-6.3 IS STM lens

▸ the EOS M100. This app allows you to extend exposures beyond 30 seconds in conjunction with the EOS M100's bulb mode, but there's no intervalometer function.

One of our test targets was the Sword of Orion region, a familiar subject in the winter months. We started by capturing Orion rising using the 15-45mm and 55-200mm EF-M lenses that came with the camera. The results were encouraging, with similar detail to what we would expect with a regular Canon DSLR. A simple 15-second exposure of the constellation's belt-and-sword region showed lots of detail, many faint stars and acceptable noise at mid ISO levels.

## Working with a telescope

Our experience using the EOS M100 with a telescope was similarly encouraging. A 30-second exposure at ISO 1600 over-exposed M42's core, as expected, but the surrounding area showed fine details, especially in the swept-back regions either side of the core. The faint ring of nebulosity, which extends in a southerly direction from the main nebula, was also captured, as was the stick figure silhouette in the Running Man Nebula, NGC 1977.

In conclusion, the EOS M100 is a great camera for ultra-portable astrophotography but it's not perfect. Like any general-purpose camera, the main sensor is fitted with an infrared filter which interferes with the camera's h-alpha response causing colour balance issues with h-alpha rich targets. The lack of both a physical connection for an intervalometer and a red screen option are issues too. And the battery life is nothing to write home about: 295 shots, or 410 shots in eco mode, under normal daytime temperature conditions. Best keep some charged spares handy. S

## Verdict

| | |
|---|---|
| Build and design | ★★★★½ |
| Connectivity | ★★★★½ |
| Ease of use | ★★★★½ |
| Features | ★★★★½ |
| Imaging quality (DSLRs) | ★★★★½ |
| OVERALL | ★★★★★ |


## Articulated screen

Camera control, image composition and review are carried out using a 75mm, 180° articulated touchscreen. This high-resolution, 1,040,000 pixel screen has five levels of brightness and displays approximately 100 per cent of what the camera 'sees' through the lens. The screen's 3:2 aspect ratio mirrors the sensor's 6,000x4,000 pixel array.

A 30-second exposure of M42 at ISO 1600 using the EOS M100 with a telescope

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# FIRST LIGHT

See an interactive 360° model of these binos at www.skyatnightmagazine.com/Opticron_binos

# Opticron Oregon Observation 20x80 binoculars

WORDS: STEVE TONKIN

## Can these budget-priced big binos compete with more expensive models?

### VITAL STATS

- **Price** £149
- **Optics** Fully multi-coated
- **Aperture** 80mm
- **Magnification** 20x
- **Prisms** BAK 4
- **Angular Field of View** 3.26°
- **Focusing** Zeiss centre focus
- **Eye relief** 17mm
- **Interpupillary distance** 56-77mm
- **Weight** 2.2 kg
- **Supplier** Opticron
- **www.**opticron.co.uk
- **Tel** 01582 726522

WWW.THESECRETSTUDIO.NET X 5

Big binoculars can be great astronomical instruments, but they are often prohibitively expensive for many. So our interest is naturally piqued when some budget-priced, 80mm aperture binoculars come onto the market, such as the Opticron Oregon Observation 20x80.

They come with a zip-fastening vinyl case with a rain flap that's secured with Velcro tabs. Unusually, the case also has a removeable, Velcro-sealed, rigid inner case with internal straps that hold the binoculars securely to reduce the effects of any bumping around during transportation. Despite the extra protection the straps offer, we found them to be a nuisance in everyday use because it's almost impossible to slip the binoculars back into their case without them snagging on the straps. Thankfully, there's a simple solution to this: turn the liner inside out so the straps are between the rigid inner and the outer cover, and therefore unable to snag the binoculars when you slide them into the case.

**SKY SAYS...**
A larger-than-standard pair of binoculars that won't break the bank with good performance

The eyepiece cover is a single, flexible rain guard-type you can tether to the strap. Typical of its design, it limits the maximum distance between the eyepieces, but it has the advantage that you can use it when the rubber eye cups are folded down. With the eye cups unfolded, spectacle wearers are usually unable to get their eyes close enough to the eyepieces to see the entire field of view. The eye cups of these Oregon Observation binoculars fold down to 2mm above the surface of the lenses, so 15mm of the specified 17mm eye relief is available. We found this to be sufficient to let us to see the entire field of view, even with our glasses on. The close focus of the test binoculars was about 30m and the focal range of the binoculars extends 'beyond' infinity, so most people with mild focus defects in their vision should be able to focus these binoculars and observe without spectacles.

### Clear, crisp views

When we shone a bright light into one of the objective lenses, only a small amount of light was ▸

## Large, multi-coated optics

Like telescopic astronomers, aficionados of binoculars have a constant desire to get more light into their instruments. All else being equal, an 80mm objective lens will collect more than two-and-a-half times as much light as the 50mm lenses that many astronomers favour for astronomy with hand-held binoculars. The result is not only that fainter point objects (stars) become visible, but that more magnification is possible without overly dimming extended objects (for example galaxies, nebulas). These, in turn, allow you to see more detail in your target object, giving more satisfying observation.

Of course, there's not a lot of point in gathering more light if it's not transmitted to your eye. It's common practice with budget binoculars for the aperture to be stopped down internally, presumably to improve the image quality. Here, the reduction is minimal: we measured the effective aperture as 76mm. Additionally, the Opticron Oregon Observer's lenses are fully multicoated, which means that compared to simple, coated lenses, at least 10 per cent more light gets through to your eye.

## Objective lens caps

Poorly fitting objective caps are about as useful as a chocolate fireguard. Luckily, the plug-in objective caps on these binoculars are excellent; they provide a tight-fitting seal and can only be removed by using the tabs provided. If you lose them, it won't be because they fell off in a field somewhere.


## Objective lenses

The objectives are recessed 16mm into their tubes, which are 11mm thick. This offers good protection against impact and accidental touching, reducing the likelihood of their surfaces getting damaged or scuffed. It also helps to reduce glare from objects just outside the field of view.

## Central mounting bar

As well as conferring rigidity between the optical tubes, the central mounting bar has a sliding mounting position, which enables you to easily balance the binoculars on the mount. This design also keeps the binoculars' centre of mass close to the mounting head's altitude fulcrum; this reduces balance asymmetry at different altitudes.

# FIRST **LIGHT**

## Carry-case

The case has side rings so you can use it like a shoulder bag, but also has three rings on the back, so you can use it like a rucksack and distribute the weight evenly across your back rather than all on one shoulder.

## Folding rubber eye cups

The soft rubber eye cups easily conform to the shape of your eye sockets, making them comfortable to use. They fold down to give an effective eye relief of 15mm, which we found to be adequate to allow us to wear spectacles for observing.



▸ reflected from its surface or the internal components, with the exception of a reflection that appeared to come from a prism surface. This illustrates the effectiveness of the anti-reflective multi-coatings. Control of stray light is also good, with minimal glare when the Moon or a bright streetlight was just outside the edge of the field of view.

We tested the binoculars under a variety of sky conditions, mounted on a photographic tripod with a fluid video head. Stars snapped to a good focus, which looked consistent over the central 80 per cent of the field of view. There was some off-axis chromatic aberration on the Moon's terminator and limb, but generally both colour correction and colour rendition were good. It was possible to easily to distinguish the colours of Alderamin (Alpha (α) Cephei), Zeta (ζ) Cephei, Delta (δ) Cephei and Mu (μ) Cephei.

These binoculars come into their own on extended deep-sky objects. The Orion Nebula was bright, showing good structure, and we could distinguish all four stars of the Trapezium (Theta (θ) Orionis). The galaxies M81 and M82 were easy to see and the differences between them were obvious. The Andromeda Galaxy, M31, nearly filled the field of view and we could detect the more abrupt cut-off owing to the dust lane on the near side. The normally difficult-to-see M33 and M101 galaxies were easily spotted when they were high in the sky, especially when we used averted vision. Although the Ring Nebula, M57, did not appear as a distinct ring, it was easy to detect and had the appearance of a disc with a darker middle.

If you fancy trying a larger-than-standard pair of binoculars without breaking the bank, the Opticron Oregon Observation 20x80s should certainly be on your shortlist, particularly if you're new to binocular astronomy. These binoculars are pleasant to use, have no glaring faults and also come with a five-year UK guarantee to provide significant peace of mind. S

## Verdict

| | |
|---|---|
| **Build and design** | ★★★★½ |
| **Ease of use** | ★★★★½ |
| **Features** | ★★★½☆ |
| **Field of view** | ★★★★½ |
| **Optics** | ★★★½☆ |
| **OVERALL** | ★★★★½ |

***SKY SAYS...***
**Now add these:**

**1.** Opticron Professional Series lens cleaning kit

**2.** Horizon 8115 two-way heavy-duty tripod

**3.** Philip's *Stargazing with Binoculars*

# Books

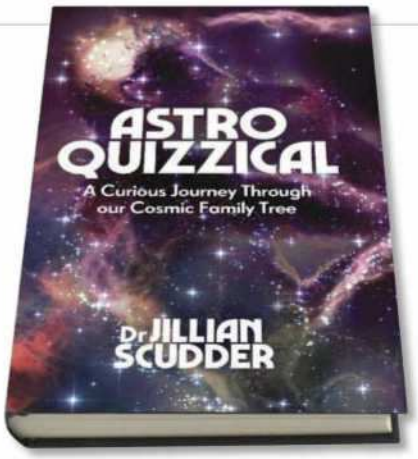
New astronomy and space titles reviewed

## RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

## Astroquizzical
### A Curious Journey Through our Cosmic Family Tree

**Jillian Scudder**
**Icon Books**
**£16.99 ● HB**

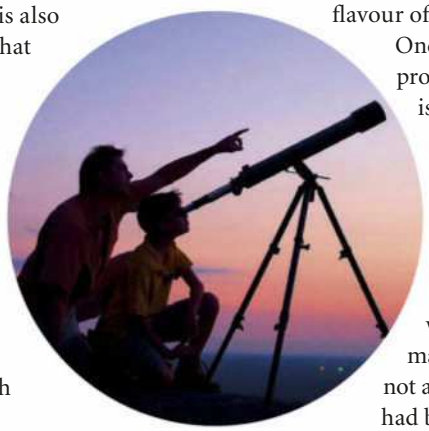



Dr Jillian Scudder is an astrophysicist and author of the successful astronomy blog *Astroquizzical*. Now, she's using her blog as the inspiration for her first venture into book-based science popularisation.

While the blog comprises an archive of fun, quirky, thought-provoking question-and-answer discussions, Scudder has decided on a chapter-based narrative for the book version. To a certain extent this approach works, though the book does lose some of the blog's character in transition, and the text is also surprisingly brief. Not that the book is without its merits, though.

Scudder's mission is to provide the lay reader with a thorough grounding in the basics of astronomical knowledge. She delivers an informative guide to modern astronomy, with most scientific terms and principles adequately explained in easy-to-follow language. The writing is fluid and direct with the subject material brought vibrantly to life.

Beginning with an overview of our human interaction with the night sky, Scudder delves into the mysteries of the Moon and the Solar System in separate chapters, and then concentrates on 'Stars', 'Stellar Deaths', 'Galaxies' and, finally, 'The Universe at Large'. Oddly (perhaps as a result of a bias in the blog question submissions), almost half the book concerns Solar System objects. Here and there the author drops in a 'thought experiment' where a particular peculiarity of astrophysics – a 'what-if' scenario – is given a thought-provoking treatment. These are welcome diversions from the main text and retain more of the meandering but entertaining flavour of the blog.



**The book of *Astroquizzical* is more for beginners than the blog that inspired it**

One of the main problems the book has is trying to fit the sheer scope of the subject matter into such a brief page count (282 pages). Some subjects are necessarily dealt with in a cursory manner (or sometimes not at all) and if Scudder had been given twice the number of pages, the result may have been much more satisfying.

Even so, for astro novices this book version of *Astroquizzical* will bring a welcome depth to their appreciation of the night sky and the wonders it holds.

★★★★☆

DR ALASTAIR GUNN *is a radio astronomer at Jodrell Bank Observatory in Cheshire*

ISTOCK

## TWO MINUTES WITH
### Dr Jillian Scudder

**What is *Astroquizzical*?**
Folks send in their questions about space and I do my best to answer them! It began after a three-hour public event at which I set up a desk that said "Ask the Astronomer" and was so busy I only had about 20 minutes free the entire evening. I figured there must be a gap.

**What are some of the best questions you've received?**
Most fun are the hypotheticals, where I have to sit down and sort out some math to figure out what would happen, like, "What would happen if the Sun split in half?" The questions from kids are good. I had one about whether the Universe was tiger-shaped.

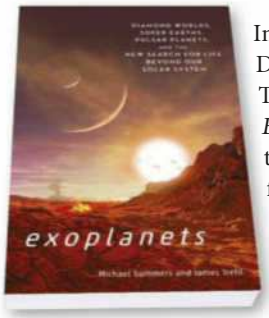
**What is the one question about the Universe that you would like answered?**
What exactly is the dark 95 per cent of the Universe? The material that makes up you and I and stars and planets is only about 5 per cent of the Universe's content. The rest is held in dark matter (about 27 per cent) and dark energy (about 68 per cent). We can describe what dark matter and dark energy do, but I'd love to know exactly what they are and how they do it.

**Your main area of study is galaxies. Tell us something fascinating about them.**
I study what happens when two galaxies collide. Even in the most direct of smash-ups, the distances between stars are so large that the individual stars won't hit any other stars. The stars' paths will change, but it's incredibly unlikely they'll actually hit another solid object.

DR JILLIAN SCUDDER *is an assistant professor at Oberlin College in Ohio, US*

# Exoplanets: Diamond Worlds, Super Earths, Pulsar Planets, and the New Search for Life beyond Our Solar System

**Michael Summers, James Trefil**
**Smithsonian Books**
**£13.99 ● PB**




In a style akin to Douglas Adams or Terry Pratchett, *Exoplanets* explores the past, present and future of Solar System and exoplanet exploration simultaneously. Aimed at a US audience, with references perhaps not as familiar to international readers, the book starts with a heavy lean towards discoveries made by the Kepler mission, although only one of the later chapters focuses on a planet discovered by the Kepler space telescope.

The book makes an effort to avoid egocentric tendencies, at times to a fault, while later chapters border on science fiction writing presented as fact, but mostly as a platform to explore more complicated ideas of planetary science and the complex nature of life in our Universe.

The authors place a particular focus on the laws of probability in nature playing thousands of dice at any time, assuming one combination will fall the way of their speculated scenario. As they say at one point, "There are sure to be planets for which this identification is correct".

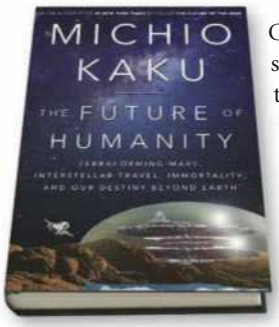
This book is for people looking for a passing knowledge of exoplanets, but who are more interested in what kinds of planets science and nature could potentially create, rather than a rigorous scientific explanation of exoplanets that have been discovered.

As with all books on this subject, this title will quickly become out-dated, but overall it is an interesting read with thought-provoking scenarios. ★★★★☆

DR HANNAH WAKEFORD *studies the atmospheres of exoplanets at the Space Telescope Science Institute*

# The Future of Humanity

**Michio Kaku**
**Allen Lane**
**£20 ● HB**




Carl Sagan once said, "If our long-term survival is at stake, we have a basic responsibility to our species to venture to other worlds." In his latest book, Michio Kaku explores the feasibility of such a future for humankind, and the scientific and technological leaps necessary to become a multi-planetary – or, indeed, a multi-galaxy – species.

Written in Kaku's easy style, this book is a comprehensive review of human space exploration past, present and future. From the early pioneering days of rocket scientist Konstantin Tsiolkovsky, he reflects on the major achievements in space exploration so far. Extending onwards into the near future, Kaku then explores the role of emerging technologies, such as artificial intelligence, nanotechnology and self-replicating robots, in creating a permanent base on the Moon or Mars. He then presents cutting-edge projects using laser sails, nanoships and revolutionary engine design concepts that could allow us to move beyond the Solar System.

At the end of the book, Kaku reflects on transhumanism, human factors and other physical modifications that may be necessary to allow our bodies to survive prolonged periods in deep space, as we search for a new home in far-off galaxies.

This is a well-researched book, positing some very big concepts on the future of human space exploration, supported throughout by well-explained science, research and expert interview testimony. While the topic at times feels vast, with some predictions based on early-stage research feeling one leap too far, the book is certainly an enjoyable and an easy read for anyone interested in off-Earth alternatives to the future survival of our species. ★★★★☆

NIAMH SHAW *is an engineer, lecturer and science communicator*

# The Victorian Amateur Astronomer

**Allan Chapman**
**Gracewing Publishing**
**£40 ● HB**

**BOOK OF THE MONTH**


This new edition of *The Victorian Amateur Astronomer* is a long-awaited update to Allan Chapman's invaluable 1998 book focusing on the astronomers who advanced the science via their own self-funded resources. As the author makes clear, the purpose of the book is to "examine the contributions made to astronomy by those persons who were not paid professionally to do so."

Victorian Britain was home to many amateur astronomers who were largely self-taught and who combined their pursuit of astronomy with the obligations of having to earn their living by other means. It is on these people that the book focuses. As a result, *The Victorian Amateur Astronomer* is primarily a book about astronomers rather than astronomy itself and is a well-written, well-researched and highly readable exploration of their achievements.

A major feature is the extensive 'Notes and References' section (spanning over 100 pages), which contains many entries that may well inspire further reading. A comprehensive and thorough index rounds off the book.

Although a small number of the illustrations are of a disappointing quality (there must have been better examples available), the sheer range and diversity of images – many of which could reasonably be described as rare – more than compensates.

*The Victorian Amateur Astronomer* is a must-read for anyone interested in the role of the enthusiastic dabbler in astronomy during the 19th century. ★★★★★

BRIAN JONES *has written 17 books on astronomy and space for children and adults*

# Gear

**Elizabeth Pearson** rounds up the latest astronomical accessories


## 1 SkySafari 6 Pro

**Price** £38.99 • **Supplier** Simulation Curriculum
www.skysafariastronomy.com

This app has everything you need to plan and carry out an evening's observations. Its colossal database has over 100 million stars and three million galaxies. Available on iOS.


## 2 Peter Storm Polar Chute

**Price** £8 • **Supplier** Millets
www.millets.co.uk

Twist this multipurpose fleece into dozens of configurations to keep your neck, face and head warm throughout a night's observing.


## 3 William Optics Vixen Dovetail Plate

**Price** £35 • **Supplier** The Widescreen Centre
01353 776199 • www.widescreen-centre.co.uk

Securely attach your accessories, such as finderscopes, to the side of your telescope tube with these dovetail bars. They weigh 0.3kg and are 200mm long.


## 4 Star Globe

**Price** £17.95 • **Supplier** The Letteroom
01264 355488 • www.theletteroom.com

Assemble your own star globe to see the stars every night. The stylish black and white design looks good during the day, then at night the stars glow in the dark.


## 5 Revelation 2-inch SCT Crayford Focuser

**Price** £123 • **Supplier** Telescope House
01342 837098 • www.telescopehouse.com

Smoothly adjust your eyepieces thanks to the roller bearings in Revelation's Crayford focuser. Comes with a 2-inch to 1.25-inch step-down ring for use with smaller accessories.


## 6 Optolong SII CCED 6.5nm 2-inch filter

**Price** £194 • **Supplier** 365 Astronomy
020 3384 5187 • www.365astronomy.com

The coatings of these SII filters are guaranteed to have high levels of homogeneity and precision, ensuring colour uniformity across your deep-sky images.

# WHAT I REALLY WANT TO KNOW IS...

# *Will the Falcon Heavy change spaceflight?*

**Professor Chris Welch** ponders the implications of the test flight of SpaceX's latest and most powerful rocket

INTERVIEWED BY PAUL SUTHERLAND

On 6 February, we saw the launch of the biggest, most powerful rocket for some time with the test flight of SpaceX's Falcon Heavy. It was a magnificent spectacle, and CEO Elon Musk's decision to make its payload his own sports car added a certain panache.

The Falcon Heavy had three booster cores, each with nine engines, so there were 27 engines firing at the same time. This made the launch a great 'science fiction moment', accentuated when two of the rocket stages landed back at Cape Canaveral at the same time.

The day didn't all go smoothly, as the middle core failed to land on a barge and crashed, but two landings out of three wasn't at all bad for such an ambitious first attempt. This was a demonstration of Musk's quest to make his rockets reusable in order to bring down the costs of getting to orbit. At the start of the Space Age, most launches were for governments and so costs weren't as much of a consideration. However, when you're providing a commercial launch service, operational costs become very important.

**Will the Falcon Heavy ever take a payload more practical into space than a Tesla convertible or is the rocket just a stopgap until Elon Musk's BFR?**

## Who will pay to use it?

This also explains why vertical-take-off rockets are still being built instead of space planes, especially by companies. For a space plane you need a great deal of money up front before you even get to fly the first one, because there's so much new technology to develop. Rockets, though, let companies take an incremental approach. With SpaceX, Musk built a small rocket, launched some payloads, made some money, then built bigger rockets and so on.

That said, and despite the success of its first launch, I don't see the Falcon Heavy becoming a terribly transformational vehicle. Sure, it would be good for heavy payloads, but just what those payloads are and who will pay for them isn't immediately clear. The classic answer is big telecommunications satellites but at the moment they are trending ever smaller because of improvements in technology.

What about launching infrastructure for Moon bases, new space stations or space hotels? Well, there are other launch systems under development, for example NASA's heavy-lift Space Launch System (SLS). Some think the Falcon Heavy will kill the SLS because Musk can launch big payloads more cheaply. But the SLS is not just about cost, it's also about jobs. If the SLS gets cancelled then the people working on it lose their jobs. US politicians who have constituents working on the SLS are likely to consider the impact of their decision on potential voters. So cancellation of the SLS is quite unlikely, I think, even if we have the Falcon Heavy.

Also, a government may decide it needs its own rocket for certain tasks rather than being a paying customer every time it needs a rocket. Especially when it comes to national security.

SpaceX's success in bringing down costs has certainly stimulated a different approach in the development of Europe's new Ariane 6 rocket. But there are other new kids coming onto the block as well. There's United Launch Services' Vulcan rocket, which has been under development for some time, as well as Blue Origin (owned by Amazon's Jeff Bezos), which has taken a different development route, starting with its fully-reusable New Shepard suborbital rocket before launching its orbital New Glenn rocket in 2020.

Even Musk is working on a bigger launcher, codenamed the BFR, which he says will be ready in five years or so. But if that has absolutely massive payload capability, what is the purpose of the Falcon Heavy? In my opinion, it may be that Falcon Heavy is risk mitigation in case the BFR is more complicated than Musk thinks and takes longer to develop.

Overall, I think the primary impact of the first Falcon Heavy launch has been on public perception of spaceflight. Firing a big new rocket and landing the stages was impressive and exciting. Launching a car into space may have been a silly stunt, but it was an original one that certainly caught the public's imagination, and which, I think, has changed people's view of space and what may be possible.

**ABOUT CHRIS WELCH**
**Professor Chris Welch is a forward-looking expert in astronautics and space engineering, and Director of Masters Programmes at the International Space University, based near Strasbourg, France**

SPACE X

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# THE SOUTHERN HEMISPHERE IN APRIL

**With Glenn Dawes**

## **WHEN** TO USE THIS CHART

**1 APR AT 00:00 UT**
**15 APR AT 23:00 UT**
**30 APR AT 22:00 UT**

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

### APRIL HIGHLIGHTS

Mercury traditionally has its best return to the morning sky for viewers in the southern hemisphere at this time of year, a result of the ecliptic being at its steepest angle to the horizon in the eastern dawn. At the start of April the planet is at inferior conjunction, but it climbs quickly out of the Sun's glare, rising just before dawn mid-month. On the 15th, its 10.5-arcsecond disc shows a phase similar to a day-old Moon. At month end its disc is only 8.0 arcseconds, but its phase is close to first quarter.

### STARS AND CONSTELLATIONS

The Southern Cross asterism is prominent in the evening sky. Its constellation, Crux, has no associated ancient legends, something you might think is because it is not visible from European or Middle Eastern latitudes. The real answer is that when the traditional constellations were named, Crux – then visible from those more northerly regions thanks to precession – was considered part of Centaurus. Mag. +0.8 Alpha (α) and mag. +1.3 Beta (β) Crucis are the 13th and 19th brightest stars in the night sky.

### THE PLANETS

Venus has moved away from the Sun, with its beacon now visible low in the west 30 minutes after sunset. Shortly after twilight Jupiter arrives, located between mag. +1.0 Spica (Alpha (α) Virginis) and mag. +1.1 Antares (Alpha (α) Scorpii).

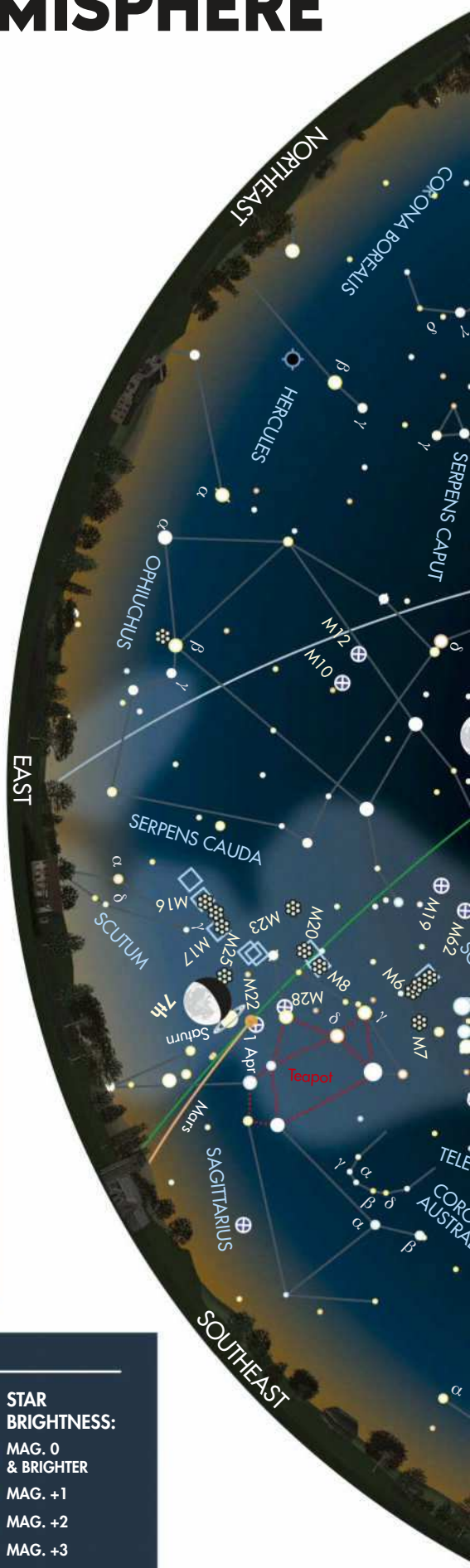
Saturn rises later in the evening (22:00 EST mid month), followed by Mars; they are only 1.2° apart on 2nd. The morning sees Neptune return (rising 03:30 EST mid month), then Mercury. This inner world is best seen in the latter half of April.

### DEEP-SKY OBJECTS

This is a great time to visit the M96 galaxy group in Leo. Look 9° east of mag. +1.4 Regulus (Alpha (α) Leonis) to the barred spiral M95 (RA 10h 43.9m, dec. +11° 42'; pictured). Visually this mag. +9.8 galaxy has a circular halo measuring 3 arcminutes across, a compact bright core and a pronounced nucleus. A low-power eyepiece might just show M95 and M96 (0.7° to the east) in the same field.

Compared to M95, spiral galaxy M96 is brighter with an obvious oval halo of 4x3 arcminutes and a more elongated core.

Only 0.8° north of M96 is mag. +9.3 elliptical galaxy M105, which has a bright, circular halo of 2 arcminutes with slight fading at the edge. M105 is part of a close trio of galaxies, forming a triangle with NGC 3384 (0.1° east-northeast) and NGC 3389 (0.2° east-southeast).

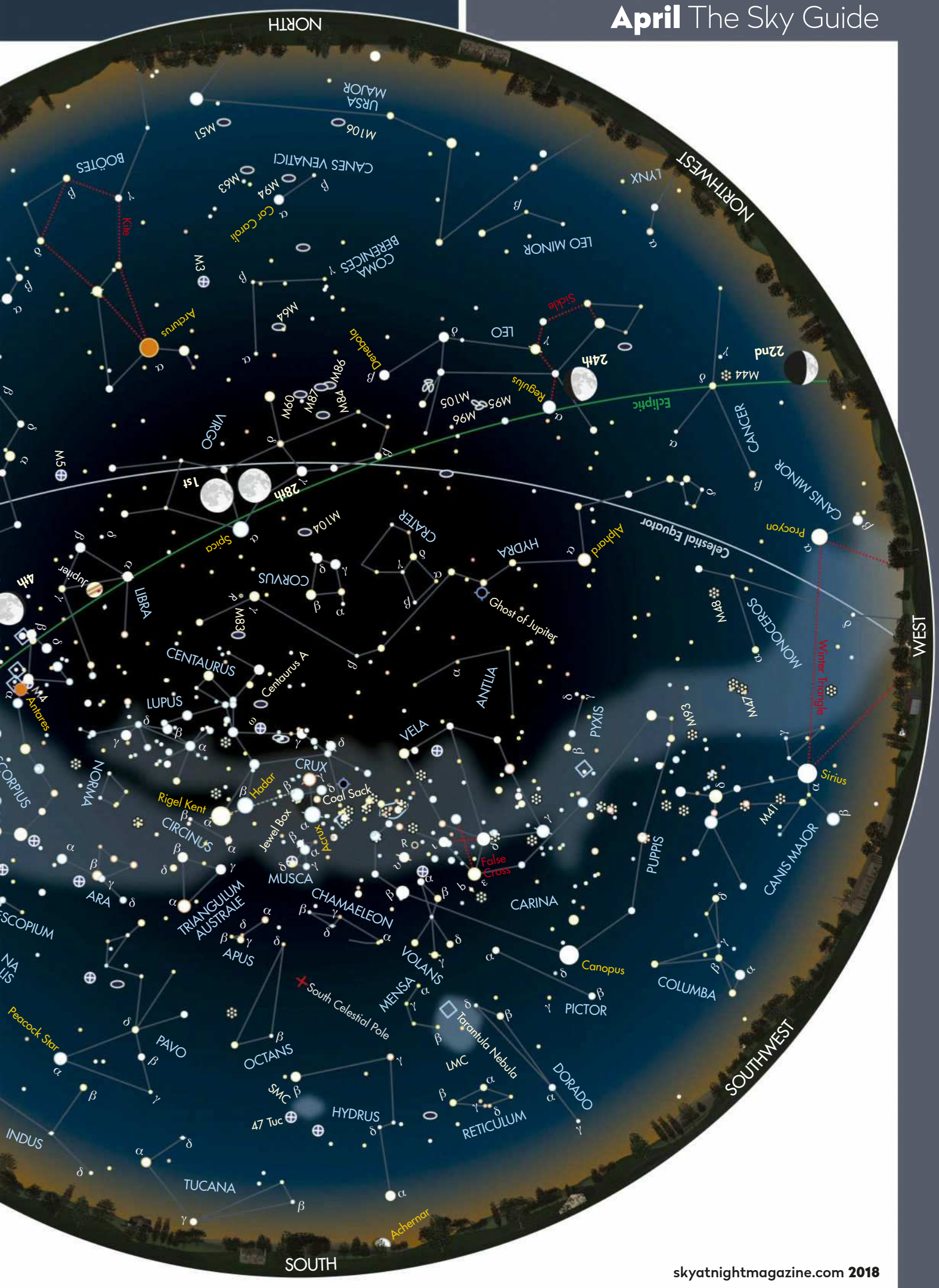



## CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: JOHANNES SCHEDLER/CCDGUIDE.COM


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
M51
M106
BOÖTES
CANES VENATICI
M63
M94
Cor Caroli
Kite
LYNX
LEO MINOR
COMA BERENICES
M3
Arcturus
M64
Denebola
Sickle
LEO
24h
22nd
M44
Regulus
M95
M96
M105
M90
M87
M86
M84
VIRGO
Ecliptic
CANCER
CANIS MINOR
M5
1st
28th
Celestial Equator
Spica
M104
CRATER
Alphard
HYDRA
Procyon
4th
Jupiter
LIBRA
CORVUS
M83
Ghost of Jupiter
M48
MONOCEROS
Winter Triangle
CENTAURUS
Centaurus A
ANTLIA
M4
Antares
LUPUS
VELA
PYXIS
M93
M47
NORMA
CRUX
Hadar
Rigel Kent
Coal Sack
Sirius
M41
CIRCINUS
Jewel Box
Acrux
False Cross
PUPPIS
CANIS MAJOR
MUSCA
CHAMAELEON
CARINA
ARA
TRIANGULUM AUSTRALE
APUS
VOLANS
Canopus
COLUMBA
MENSA
South Celestial Pole
PICTOR
Peacock Star
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